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ABSTRACT

This teaching guide is one of a series developed by the Curriculum Research and Development Group at the University of Hawaii. The program is laboratory and field oriented for elementary students. The focus of study for the project is the plant and animal life and the physical components of the Hawaiian environment, and their ecological interrelationships. The program stresses student on-site observations, experimentation, discussion, and learning by experience. It is designed to fit within the science curriculum but can correlate with other subject areas in school, as well as with local community interests. This particular guidebook on the reef and shore is prepared to give teachers ideas for activities and investigations which K-6 students can pursue to learn about the ecology of Hawaiian shallow water and shoreline areas. There are two major sections to the guide: (1) Information and Techniques for Teachers; and (2) Investigations for Students. Section one includes information on organizing field trips and setting up aquaria. Section two is concerned with marine plants and animals. There are numerous illustrations and charts for the teacher. This series also includes a teacher's program manual containing additional information. (Author/MA)

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HAWAII

NATURE STUDY PROGRAM

FOR ELEMENTARY SCHOOL CHILDREN

REEF AND SHORE

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Teacher's Guide

A project of

CURRICULUM RESEARCH AND DEVELOPMENT GROUP
University Laboratory School
UNIVERSITY OF HAWAII
1776 University Avenue
Honolulu, Hawaii 96822

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SE 023 247

REEF AND SHORE

HAWAII NATURE STUDY PROJECT

by the

CURRICULUM RESEARCH AND DEVELOPMENT GROUP
UNIVERSITY OF HAWAII

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THE HAWAII NATURE STUDY PROGRAM

The Hawaii Nature Study Program is an environmental science education program for elementary students comprised of out-of-door, action-oriented, problem-solving observations and investigations about the natural and man-made environment of Hawaii.

The Hawaii Nature Study Program uses the methodology and language of science. It fits as a local Hawaiian portion within the larger scope of any standard science curriculum. Classroom teachers also use Hawaii Nature Study activities in conjunction with art, music, social studies, crafts, and the language arts to give expression to the human, artistic, and communicative aspects of environmental topics.

The goals of the Hawaii Nature Study Program are to promote in elementary children awareness, appreciation, knowledge, understanding, and valuing of the environment. Great flexibility is provided in that each topic is presented at three BANDS or levels of difficulty. Teachers are encouraged to select topics and BAND levels appropriate to their grade or situation.

The printed materials of the Hawaii Nature Study Project consist of:

1. a PROGRAM MANUAL, separately bound, which contains a complete description of the program and its goals, together with an explanation of the BAND levels, suggested teaching strategies, teaching aids for managing campus and neighborhood investigations, data analyses, and student reports.

2. TEACHER'S GUIDES divided by subject into six books entitled PARTS OF PLANTS; INSECTS; SMALL ANIMALS OF THE SCHOOL NEIGHBORHOOD; SOIL, WATER, AIR; MORE PLANTS; AND REEF AND SHORE.

REEF AND SHORE

This Teacher's Guide on REEF AND SHORE is prepared to give teachers ideas for activities and investigations which Kindergarten to Grade 6 students can pursue in the field and in the classroom-laboratory to learn something of the ecology of Hawaiian shallow water and shoreline areas.

Section 1 of this book is devoted to general procedures and advice about arranging field trips, setting up aquaria, and other points useful in managing studies about the reef and the shore.

Section 2 is a series of specific marine topics. Each topic begins with those which are simple to do and require little background, and progresses to those which are more difficult or require previous student experience.

Problems:

Boxed problems are statements and questions which can be given to students either as they are, or modified, selected from, augmented, or reduced to fit grade and interest level.

Boxed problems are accompanied by Suggested Procedures and Background Information which each teacher can use, modify, expand upon, omit, or use to suite individual needs. See the PROGRAM MANUAL for further advice on the initiation and management of laboratory problems and data, scientific reporting, and students' notebooks.

Before getting into the investigations on REEF AND SHORE, pilot teachers have found it adviseable to establish two important preliminary attitudes with the students. (1) Because of the fragility of the marine ecosystem, students need special reminders about conservation practices. (2) Because of the sensitivity of students toward life and death occurrences in nature, students need a preliminary discussion about predator-prey relationship and about high mortality rates among highly prolific marine animals.

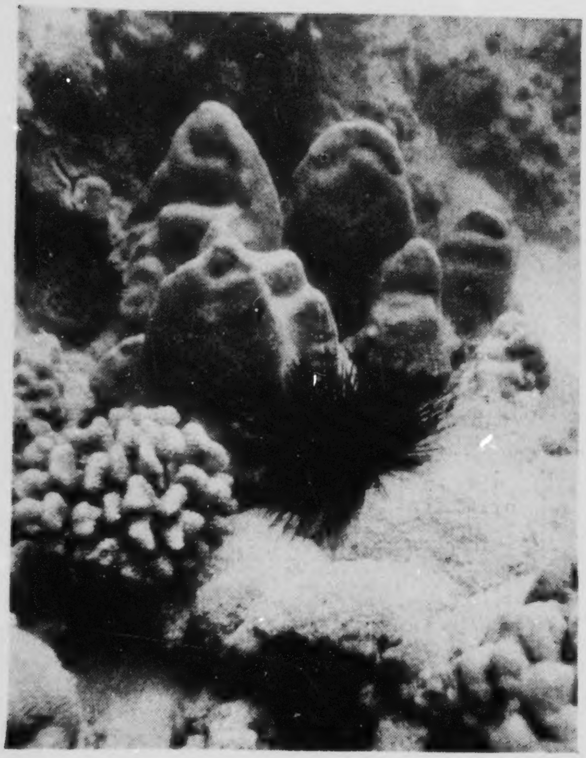
MAHALO

Numerous persons have generously contributed to the compilation of this book. Sayo Nakagawa, a fine arts graduate and Technical Assistant to the project, has been the REEF AND SHORE layout artist, final-copy typist, and office manager. Barbara Culliney, who has a Masters degree from Scripps Institution of Oceanography, has developed field tested, and written the sections on Sea Anemones, Corals, and Crabs and Shrimp. Dorothy Buddemeier is an elementary teacher and reading specialist who took on a fifth grade class in science in which she developed, class tested, and did the initial writing of the Deep Ocean topics. Dorothy also served as field consultant to the pilot teachers, assisting them with the testing of the drafts.

The pilot teachers have labored through the rough write-ups of REEF AND SHORE, trying the activities on their classes and giving valuable feedback to the project on their findings. Contributing to an all-day critique session at the end of the test year were Yvonne Toma, Sister Joyce Marie, SS.CC., Dorothy Wendt, and Kathy Chock, along with the staff persons mentioned above. Further valuable contributions have been made by Magdalene Cambra, Dennis Kawamoto, and area groups of pilot teachers at Kipapa, Wilson, and Kamiloiki Schools.

Staff time and efficiency have been greatly augmeted by the expertise and gentle patience of our fiscal officer, Myrtle Yamada.

Partial outside funding sources for REEF AND SHORE have come through the Hawaiian Academy of Science and from Sea Grant 04-6-158-44026. Individual members of the Hawaiian Academy of Science have been generous and helpful in reading and critiquing the manuscript.



Coral reef at 20-ft depth off North Coast of Kauai. *Diadema* sea urchin at base of *Porites*. *Pocillopora* at Lower left.
Photo by A. S. Reed

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1. FIRST YEAR OF REEF AND SHORE . . . AND THEREAFTER

This book on REEF AND SHORE, like other Hawaii Nature Study books, includes problems and activities for use across a span of seven years: Kindergarten through Grade 6. It is not likely, nor even desirable, that any one class or teacher will cover all the REEF AND SHORE experiments in any one year. Besides the sheer volume of materials and the time involved in doing them, REEF AND SHORE topics are somehow more "frightening" to get into than experiments about campus plants or insects. Even experienced upper level teachers spend their first year of marine studies "stumbling around," trying out what will work for them and what will not, finding which location in their classroom gives the best light and darkness for a successful marine tank, gradually accummulating knowledge of which shorelines within reach of their school yield the best specimens and what kinds.

The first year of getting into REEF AND SHORE studies, regardless of grade level, needs a light touch. Keep in mind that interest and stimulation are prime goals at the elementary level. The children will not be required to take a Ph.D. examination in marine studies at the end of fourth grade, not even at the end of sixth grade.

Ideas for First Year of REEF AND SHORE Studies (any grade level).

Idea #1. Do those experiments which do not require an aquarium. Take the topic on salt water, build the "big box" of deep sea animals, mount sea weeds, bring into the classroom only those animals which can be maintained in a shallow pan for a few days, such as hermit crabs. Omit having an aquarium. Even omit field trips except perhaps a trip to the Waikiki Aquarium.

Idea #2. Build and maintain a classroom tank (Section 1., Topic 5). The entire year's work can consist of making simple observations and of learning how to keep a tank going with marine invertebrates. This could be begun by the teacher with the students looking on. By October the students ask to "help." By January they have taken over the duties of feeding and maintaining the tank (with periodic disasters and need to start over). If nothing more happens during the first year than engaging interest in and learning the techniques of maintaining a salt tank, the year has been well and profitably spent.

Idea #3. Prepare for, and go on several Extended Field Trips during the school year. Plan agenda of things which can be pursued at the beach without bringing anything back to the classroom which requires care. For example, do a tidal pool survey, study the shoreline land plants, spend a day, or a week, working on sea weeds, survey zonation in nerites and periwinkles, chase sand crabs. Classroom work, without a tank, can consist simply of preparing well for the field trips and making follow-up reports.

Ideas for a Second Year of REEF AND SHORE Studies.

Idea #1. Have another "first year." If the previous year was spent doing non-tank topics, this year set up and learn to maintain a tank. Or, if the first year was spent doing nothing but learning how to maintain a tank, then do non-tank experiments this year, or do extensive field trips this year.

Idea #2. Build on the interest and limited experiences of the first year. If the first year was spent simply learning to maintain a tank, then this year select some of the problems or experiment on invertebrates using the class tank.

Idea #3. Try a potpourri: Go on one field trip; do some of the class tank experiments; take some non-tank activities; select the easiest parts (BAND 1) portions of many different topics.

Ideas for Subsequent Years of REEF AND SHORE Studies.

Try any of the problems and topics in this book for which the class shows the capabilities and interest. In upper elementary grades encourage students to inititate problems of their own, and design experiments to answer their own questions. Work for greater proficiency in notebook reporting.

Ideas for Veteran REEF AND SHORE Teachers and Classes.

In primary grades, veteran teachers can continue to introduce their youthful new classes to simpler activities and care of a tank, doing the easier observations. Primary children may not get into any of the investigations beyond the observation level. They become very unhappy when their animals undergo even natural death.

Upper level elementary teachers who have done REEF AND SHORE activities for two or more years and whose incoming classes have had introductory work with tanks and simple experiments, will find appropriate challenges in the BAND 3 problems. BAND 3 experiments nearly always require some background either in tank techniques or experimental design or both.

Upper level teachers may get into those experiments which require mathematical work such as determination of percentages of salinity in sea water, calculation of how many grams of food intake produces how much weight gain in Aplysia. The last section on Deep Ocean offers points of departure for getting into encyclopedia and library research on topics beyond those outlined in this book.

Students who have gotten through most of the experiments in the REEF AND SHORE book can move on to doing some field work on their own, finding further marine organisms to become acquainted with. They can become adept at tank maintenance as well as at scientific experimental techniques and reporting.

2. CONSERVATION

Conservation is defined by most of those professionally engaged in its practice as the "wise use" of our natural resources. The "use" part of the phrase allows utilization of our resources, while the "wisdom" part regulates and controls their depletion with an eye toward survival and usage for the future.

This ethic is consistent with modern Western mentality which sees man as the master and the steward of nature, the power responsible for the world's productivity, protection, and well-being.

There are other views. Some Eastern philosophies see man as the peer of other living things, as a co-being who should neither harm nor exploit universal life of which he is a part. We read in American Indian literature that the "land" is our mother and we are shaped by her, not vice versa.

Whatever the philosophical approach, the practice of conservation comes down to a few dicta which cannot be brushed aside.

1. Every living thing, as well as non-living thing, has a place and function in the balance of existence on the surface of this planet, whether or not we happen to know what its precise niche is. "Everything is connected with everything else." "Everything affects everything else." Destruction of one species, useless and unimportant though that species may seem to our ignorance, can have wide-reaching repercussions.

2. Natural resources are exhaustible. Populations which drop below a critical threshold cease to reproduce and the species plummets into extinction. Energy resources on earth are not renewable. Extinction of living species and exhaustion of non-living resources are natural processes. Trilobites went extinct before man appeared on the scene. Volcanoes spew noxious gases into the air. Nevertheless the speed with which man, especially 20th century man, is destroying or using up extant life and resources is astronomical compared to natural processes.

3. Since man is an intelligent being, he can, if he will, desist from extinguishing life and exhausting the resources of the earth. Man can practice conservation without denying himself a full and enjoyable life. His reason for using resources wisely may be an idealistic appreciation of all that nature has and is, or it may be a realization that our tomorrows will be poorer unless wisdom regulates usage of our goods.

For elementary children engaged in visiting reef and tide pool areas, conservation comes down to a few simple practicalities.

-Do visit the reef or shore for study and enjoyment, but when you depart, leave the area the same, or better, than you found it.

-If you turn over a rock to see what is hiding under it, turn the rock back again when you are finished looking. What lives under the rock may depend for survival on the kind of micro-habitat on the underside.

-If you pick up plants and animals for closer viewing, disturb only the few you need to look at. If you know a species is rare, or if it seems to be, do not disturb it at all. Just look.

-If observation and investigation require detailed or prolonged study, and if your class tank is adequate, collect and bring back to class what is needed for study. When the class study is finished, return the living specimens to the reef whence they came.

A Sheller's Creed, published by the Hawaiian Malacological Society, was composed for its shell collecting members. The sentiments expressed in the creed apply equally to all our reef and shore activities.

A Sheller's Creed

The wild life and natural resources of these islands have been entrusted to me for protection and preservation. Whether I wish it or not, I must account to the future for my handling of this wealth today.

If I collect shells, I will do it conservatively, recognizing that destruction of the marine habitat, by whatever means, is the true enemy of the sea and its creatures.

3. FIELD TRIPS

Definition and Types.

Excursions to the shoreline for the purpose of observation and study may be brief errands to a beach area to accomplish a specific task followed by immediate return to school (SHORT FIELD TRIPS), or they may be half-day or all-day class events (called here EXTENDED FIELD TRIPS).

Values.

Extensive and repeated first-hand field exposures are a peerless vehicle for building knowledge about and sensing the beauty of the real world in which we live. During well-planned field trips students engage in group action, form environmental attitudes, collect scientific data on assigned problems, and enjoy the artistry of nature.

Lasting impressions and life-long loves are engendered during field trips (including field trips which go by the name of family outings and camping out). As adults, we can recall that many of our most vivid and fruitful lessons stemmed from early "reality experiences" as opposed to those whose sole origin was descriptive reading or passive listening.

By means of field trips, students relate a classroom activity to a local reality; they associate the discussion topic with the actuality of ocean, shoreline, and reef. It would seem more efficient and uncomplicated for a teacher to be provided with specimens by a field consultant assigned to the special task of providing live specimens to classroom teachers, or to have the teacher alone or with a few helpers collect the needed materials for class work. But the goal here is the education of the students and that goal is best accomplished when students see, feel, and experience living specimens in the shoreline habitats of those animals.

A field trip can be a valuable sociological learning experience, giving practice in group planning, group cooperation, travel, eating out, and public "behavior". As much as possible, the students should share in preliminary planning and management of the trip as well as in responsibilities during the excursion. A good rule of thumb here, as elsewhere in teaching, is "Never do anything for the students which they can do for themselves." Even small students can assume small responsibilities in the preparation and conduct of a trip.

Times and Numbers of Field Trips.

Any time of year is good for a field trip. Academically, the most useful time is when a set of problems is under study which needs field data.

Field trips organized early in the school year usually yield greater learning benefits than those undertaken for the first time in April or May.

Regarding numbers of trips per year, it would be ideal to be able to hold all REEF AND SHORE classes out on the reef and along the shore! We are limited by available facilities, time, costs, transportation, and the scheduling and needs of other school subjects, but we can aspire to take students out as often as possible, on trips pre-planned to be as rich as possible in scientific, sociological, and aesthetic experiences.

Short Field Trips.

Short Field Trips take a short time, perhaps only a double class period, or a class period added to a lunch period. Short Field Trips must be carefully planned to accomplish maximum work in minimum time. Usually they are devoted to one specific observation or collection followed by immediate return to the classroom for follow-up discussion or handling of the collected materials. A temptation to be avoided is having a few students bring in specimens for the entire class, a procedure which short-circuits a valuable field learning experience for the class as a whole.

Sample Agenda for Short Field Trips.

Example #1. Short Field Trips to Tidal Pools:

Pre-field trip.
- Prepare for tidal pool observations. See Tide Pool lesson.

Field trip.
- Leave for beach area in private cars. Travel time perhaps 15 to 25 minutes.
- Students gather around previously indicated tide pools, take notes on what they see. Quiet observation for perhaps half an hour.
- Return to school immediately.

Post-field trip.
- Discuss in class what was observed. Compare notes. Write reports.

Example #2. Short Field Trip on Sea Weeds.

Pre-field trip.
- Prepare for sea weed work. Have materials for pressing ready in classroom before leaving for field.

Field Trip.
- Leave for beach area in chartered bus. Travel time perhaps half an hour or less. During bus trip play observation games such as how many such and such type of trees are seen on the way; or temperature variations in school yard, bus, at destination; cloud types seen during trip; etc., etc.
- Collect sea weed in limu bags. Each group collects its own according to its needs and no more.

-Note places from which each type was taken, how many there were. See Sea Weed lesson for observations to be made while collecting.

Post-field trip.
-Immediately upon return, make the first "sea weed sandwich" of mounted specimens.
-Change to dry papers and cloths as needed on succeeding days.
-Label and identify pressed specimens.

Example #3. Short Field Trip to the Waikiki Aquarium.

Pre-field trip.
-Prepare for visit by considering which displays or conducted tour will be given attention during time to be spent in the Waikiki Aquarium. (See Topic 5 of this section.)
-Call the Aquarium for suggestions and arrangements. Note references to Aquarium in several topics in this book.

Field trip.
-Carry out the plans as arranged with the Aquarium.

Post-field trip.
-Return immediately to school. Discuss what was seen and learned.
-Have students make notebook reports with diagrams.

Example #4. Short Field Trip on Any Topic (See lessons on Hermit Crabs, Sea Anemones, and other topics in Section 2.)

Pre-field trip.
-Prepare for trip by going over with students what is to be done, observed, or collected.

Field trip.
-Travel to site. Play "games" on the way using passing roadside observations.
-Make planned observations or collections at the site.
-Return to school quickly.

Post-field trip.
-Discuss observations, collections, and/or carry out experiments on materials brought back from the field. Make notebook reports.

Extended Field Trips.

Extended Field Trips have the advantage of lasting long enough to allow for both in-depth study of one topic and exposure to multiple topics.

In the science components of an Extended Field Trip, students can make observations, complete measurements of field situations, and conduct on-site tests. There is time to sit down together in the sand or on the grass and discuss data. Often a second set of data can be collected in the afternoon to give comparison or contrast to what was observed in the morning.

An important component of any Extended Field Trip to the reef and shore is the portion given to an aesthetic experience of the sea. A definite time for joy and appreciation should be planned into every trip, e.g. listening to ocean sounds, scuffing in the sand, writing a poem, sketching a scene, making a drift wood boat, etc. This is not free play time. The artistic dimension needs to be skillfully planned. Specific ideas and procedures for aesthetic activities are suggested in Topic 6, entitled "Art, Music, Poetry, and Stories of the Sea."

Planning and Preparation.

Preparation and follow up work for Extended Field Trips is the same as for shorter trips except that since multiple topics must be prepared for, the preparation time is longer, extending perhaps to several days or even weeks on both sides of the trip.

The components of science, social action, aesthetics, and other dimensions which are part of an Extended Field Trip may be arranged in many different ways and with different accents. Conditions vary greatly from site to site, school to school, time to time. The following examples may stimulate ideas about some possibilities.

Sample Agenda for Extended Field Trips.

Example #1. Extended Field Trip to a tide pool area at low tide.

Field Work.

- -Observation of designated student groups around designated tide pools with note taking. (See Tide Pool lesson.)
- -Group and class discussion, while sitting on beach, of what was observed.
- -Do physical measurements of tidal pool area (temperatures, sizes, etc.).
- -Make population counts on nerites, periwinkles, and other animals of the intertidal zone, noting heights above low tide level. (See lesson on Nerites and Periwinkles.)

- -Lunch.

- -Build sand castles, sort out different kinds of sand grains, make sand pictures.
- -Sit on beach, each person alone or in small discussion groups, and make observations on incoming waves, direction of ocean currents near shore. Watch manner in which incoming tide destroys sand castles.
- -Observe differences in clouds over ocean and over land, near ocean horizon, and over mountains.
- -Note height (or depth) of reef flat and consider geological eras, subsidence, consolidation, erosion, benches.

Example #2. Extended Field Trip on Land and Sea Plants.

Field work.

- -Observe shoreline land plants while going from parking lot to beach area. (See lesson on Shoreline Land Plants.)

-Collect limu, working in small groups as decided previous to trip. (See Sea Weed lesson.)

-Spread out equipment on beach and mount specimens. Prepare first "sea weed sandwich" with newspapers and cloths, to be weighted when returning to class.

-Lunch.

-Move to a less disturbed area of beach and look for crab holes in the sand. Count density of holes, sizes, chase crabs. (See lesson on Crabs.)

-Gather together for a sea story, or have students make up a story as they rest on the sand, each one adding a new event into the fiction.

Example #3. Extended Field Trip - Any Set of Topics.

-Plan a variety of experiences according to what the season and the nearest shoreline has to offer. Include an aesthetic experience in the agenda.

The following check lists may assist in the tasks of getting ready for Extended Field Trips.

Check List of Permissions and Permits.

-Permission of school principal or department leader.

-Permission slips to go home for parental signature (one student might collect and alphabetize these).

-Swimming permissions.

-Permit from the Department of Parks and Recreation for use of ocean site.

If the group contains fewer than 50 persons, no permit is needed.
If 50 or more persons are in the group, a permit is required.
If you are on Oahu, apply to:

Department of Parks and Recreation
Honolulu Municipal Building
650 S. King Street
Honolulu, HI 96813

You may also apply at any of the satellite city halls.
If you are in Kauai, Hawaii, or Maui County, apply to the Parks and Recreation Departments of those respective Islands.

Send the following information:

Name of park to be visited
Date and hours of visit
Number of persons in group
Name of person in charge

There is no charge. A permit will be sent to you which includes regulations about litter, camp fires, and other items.

Check List of Arrangements.

-Transportation: private car? chartered bus? public transportation? costs?

-Arrangements for students who come late, miss transportation, forget lunch.

-Lunches: brown bag? cold drinks? refreshment stand at site? costs? (Students might be able to work out this part of the planning.) Inform school cafeteria of absence of class from school on given day.

-Notification to neighboring teachers whose class or classes overlap with the teacher or with the class on the field trip.

-Coverage of student duties (JPO, cafeteria, monitor duties) of students who will be away during duty times.

Check List of Academic Preparation.

-Clarify the study problem(s) to be pursued during the Extended Field Trip.

-Do preliminary discussion, reading, planning on problem.

-Group students for division of labor in the field.

-Show map of area, mark sites in which different groups will work.

-Prepare blank data sheets (student job).

-Plan for at least one aesthetic experience during the day, e.g. sketching, poems, listening to natural sounds, story telling, etc.

Check List of Equipment.

-Determine field equipment needed for the tasks (nets, look boxes, buckets, art supplies, etc.)

-Gather equipment. Divide it into sets for group use.

-Assign students to "inventory" the equipment for each group when leaving school and again when leaving the field to return to school.

Check List of Other Planning Items.

-Additional chaperones or teacher aides to go along.

-Require appropriate clothing. No bare feet on coral reef. Zoris strapped to feet with strips of cloth are acceptable for primary children who claim they have no solid footwear.

-Lay out rules for getting into water, when, to what depth. Wading to ankle depth only is an appropriate rule for classes of small children, even when chaperoned. This is also consistent with current Department of Education regulations.

- -As a point of information, in case of need or accident, find out which chaperones can swim or have life saving certificates.
- -Is the first aid kit in good condition? Have one person responsible for bringing it along and bringing it back to school afterwards.
- -Where is the nearest phone booth to the site to be visited?
- -Arrange with one parent who can hurry to the site in a private car in the event that a student becomes ill or is in an accident.

Back-up Plans.

- -Have a "Plan B" to use in the field in case rain or unforeseen difficulties wipe out a part of the planned program.
- -Have a "Plan C" to use in case the entire field trip must be cancelled at the last minute.

4. TIDE CHARTS

Information on the heights of tides is essential for the planning of field trips. At low tide, intertidal areas become accessible. The lowest of the low tides at full and dark phases of the moon particularly in Spring are the most productive and easiest times for observing and collecting. Even beach and upper shoreline studies are done more easily at times of low tide.

The daily papers carry lists of times and heights of tides at Honolulu with an appended set of correction figures for estimating maximum and minimum tides elsewhere around the Islands.

Tide calendars are printed and distributed free of charge by the Dillingham Corporation, Box 3468, Honolulu, Hawaii 96801. The Dillingham tide calendars are easy to read and make beautiful wall hangings. Because of popular demand they are distributed one to a household upon special request, preferably to those who make use of them.

Tide charts in black and white replicating the Dillingham calendar are printed in the monthly Sea Grant Newsletter distributed free of charge to those who ask to be on the mailing list. Apply to the Sea Grant Publication Office, 2540 Maile Way, Spalding 253, University of Hawaii, Honolulu, Hawaii 96822.

5. THE WAIKIKI AQUARIUM

Description.

The Waikiki Aquarium is a public educational facility of the State of Hawaii operated under the aegis of the University of Hawaii.

The Waikiki Aquarium began operation in 1904. The present building was completed and opened to the public in 1955.

A variety of live and static exhibits are designed to teach and delight aquarium visitors. Approximately sixty tank exhibits contain live marine and freshwater animals. Many of the tanks are arranged to depict a typical marine community.

Seals and sea turtles are kept out-of-doors in a seal pool with undersea windows for subsurface viewing.

Currently decorating the interior walls of the Aquarium and in cases in the Marine Science Museum are exhibits of corals, shells, and other sea animals from Hawaii and the Indo Pacific. Other displays on oceanographic subjects are being constructed.

The Waikiki Aquarium is located at 2777 Kalakaua Avenue, on bus line #2 or 14. Hours of public operation are:

10:00 am to 5:00 pm, Tuesday through Saturday
1:00 pm to 5:00 pm, Sunday
Closed on Monday

School Tours.

The Waikiki Aquarium offers guided tour programs to public and private schools, Kindergarten through college. To assist the teacher in selecting and preparing for a tour, Aquarium Tour Booklets have been placed in school libraries throughout Oahu. If your library does not have these booklets, please contact the Aquarium Education Department and they will be mailed to your library.

Outer island schools wishing to tour the Aquarium should write to make an appointment for any time during operating hours.

For tour times for Oahu schools, appointments may be made at 9:00, 10:00, and 11:00 am, Tuesday through Friday, throughout the regular school year. Book your tour well in advance.

Tour Appointment numbers: 923-4725 or 923-9741

Contact the Education Staff at the Aquarium for assistance with any special preparatory problems.

When you reach the Aquiarum, inform the cashier of your arrival. A Docent will greet you, guiding your group from that point on.

The introductory lecture and tour will take approximately one hour.

If your class wishes to bring lunch, ample grass area surrounds the Aquarium compound.

Standard Tour Topics.

Tours are available on the following elementary topics and levels:

1. Kindergarten to Grade 3 Topic: Animal Protection or Animal Clothing. Program: A "Touch Basket" talk followed by a tour.
2. Grades 4-6 Topics: Animal Protection (Gr. 4); Dangerous Marine Animals (Gr. 5); Tide Pools (Gr. 6). Program: A slide/tape lecture followed by a tour emphasizing topic concepts.
3. Other topics, used mainly for older grades, include: Sandy, Rocky and Coral Communities; Camouflage; Marine Animal Communication. These topics can, in some cases, be adjusted for younger groups.

Special Tours.

Teachers engaged in the Hawaii Nature Study Project who are carrying out REEF AND SHORE problems and activities will find special displays at the Waikiki Aquarium which correlate with their special needs. For example, the activities with hermit crabs as described in REEF AND SHORE are complemented at the Aquarium by a small tank in which various species of live hermit crabs are displayed. Check with the Waikiki Aquarium to confirm whether the marine topic you are currently considering has a special display.

If you are studying a special marine topic with your class for which the Waikiki Aquarium does not have a standing exhibit, the Education Department at the Aquarium will cooperate as far as possible to give your class a special lecture or demonstration suited to your needs. This requires at least four weeks notice.

6. ART, MUSIC, POETRY, STORIES OF THE SEA

Introduction.

The poetry, art, music, and literature of the sea merit a fair share of nature study time during which the seeds of appreciation, love, and joy in the ocean world can be embedded in young students' feelings and imaginations. Most youngsters are quickly responsive to aesthetic values when they are presented through an appropriate stimulus. In children, education toward the savoring of beauty usually profits from a light structure, within and through which preferences can grow at their own pace.

An Extended Field Trip is one occasion which might schedule a slice of time for building unforgettable memories about the beauty and mystery of the ocean. Planned, but free-flowing, sallies along the shore give opportunity to exult, with wet feet and wind-blown hair, in the sight, sound, smell, taste, and "feelings" of the sea.

Another means is to introduce an experience in beauty in the classroom. From there students may be encouraged to take a moment, or an hour, of their private time, perhaps during a family beach picnic, to sit and dream, to wander and wonder, to breathe the salt air, to listen to the pounding waves.

Some teachers, particularly elementary teachers, are very creative and skillful in thinking up ways and means of exposing their students to activities which promote appreciation. Following are descriptions of a few ideas which teachers have used to provide a climate for the contemplative enrichment of their students.

The U.S.D.A. Forest Service Picture and Poem Activity.

Mrs. Betty Reinke, Information Officer for the U.S.D.A. Forest Service, has an exercise she includes in field teacher training sessions. She has teachers go through the exercise themselves as they learn how it is done. Her instructions to the teachers go something like this:

1. Toward the end of a working session in the field, gather the students together and distribute to each a sheet of sturdy paper, e.g. heavy typing paper or pale-colored construction paper.

2. Ask students to "paint" a picture, any picture of their choice, using only natural materials as media. For example, flowers may be crushed to get colors, grass or leaves may be rubbed onto paper to obtain greens, soil or pieces of rotting log may yield browns. Have some pieces of charcoal to give to students who "can't find anything" to paint or draw with.

3. Each student is to work alone, preferably beyond the sight and sound of any other student, but within the designated camp area. The aloneness opens ears to sounds which are otherwise missed.

4. Use a whistle to bring the students back to the camp center in about 20 minutes or half an hour.

5. Have the students sit in a circle on the ground. Plastic garbage bags, spread out, make good "mats" on which to sit.

6. Invite the artists to show their pictures to one another and explain them if they wish.

7. Direct the composition of a poem (without explaining that this is what it is) as follows: (Pause after each direction for carrying out the instructions.)

   -Somewhere on your picture write THREE ACTION WORDS about your picture.

   -In the next line write a SHORT PHRASE which tells the VALUE OR USEFULNESS of what you have pictured, i.e. four or five words about its place in the environment or any thought you might have about it.

   -Now write ONE WORD which sums up everything you have thus far written.

   -Congratulations! You have just composed a poem.

8. Students who wish to do so may read their poems to the group.

Haiku.

Children in Hawaii can easily be interested in writing haiku. The elementary children at Punahou School wrote haiku verses about ecology and the environment which were used as spot public service announcements one year on a TV station. The two Honolulu daily papers sometimes publish children's haiku.

The rules for haiku are:

-The first line has 5 syllables

-The second line has 7 syllables

-The third line has 5 syllables

-Total = 17 syllables.

The number of words may vary, but never the number of syllables. The words need not form a complete sentence nor need they rhyme. Haiku does not give explanations nor meanings. Haiku expresses a feeling, a mood, or conveys an impression. The haiku poet presents an object, usually of nature, around which he has had an intuitive experience, and exposes his experience subtly to his audience.

Perhaps some of your students would care to try a haiku about a frigate bird soaring above the ocean, or about white caps breaking at the edge of the reef, or about dark rain clouds on the horizon.

Poetry Reading.

The school library shelves may yield some simple poems about the sea which the students might enjoy listening to, memorizing, putting a tune to and singing. "The Owl and the Pussy Cat" might be a starter for the little children. John Masefield's "Sea Fever" might appeal to the older ones; or use whatever the library shelves yield.

Sea Stories.

Consult your school librarian for whatever stories about the sea are available for your grade level. These could be read to the students in class. Older students might care to read them privately and then act out one or two scenes as a book report to the class.

Students might make up their own stories around a sea theme as part of their English composition class. Start them off with one sentence. Sample assignments might be:

- Write a story about the sea. The last sentence in the story will be "Dawn broke, and there, riding proudly at anchor just beyond the reef, was the white ship."
- Here is a first sentence to which to attach a story: "Six strong pirate ships raced for the island, each manned by a lusty crew thirsty for Aztec gold."
- Write a story in which these sentences are somewhere included: "This was Celia's first long swim away from her parents. Never before had she been out of sight of the pod of adult whales."

Inspirational Writing at Claremont.

When Dr. Edwin Phillips of Pomona College in Claremont takes his graduate botany students on day-long field trips he includes the assignment that during one-half hour of the day each student walk alone and in silence among the trees, across the grassland, along the beach, or wherever the field trip is targeted, simply to soak up the "feeling" of whatever is there. They later express their experiences in poetry, art, essays, or in any way they choose, which they may or may not share with the rest of the class. This idea for graduate students could be boiled down to elementary school level by an imaginative teacher.

Sea Chanties and Other Sea Songs.

Songs about the sea could be learned by heart in the classroom, then sung together at the beach with everyone sitting on the sand watching the waves break. Some students might be inspired to engage in free-form dancing to accompany the wind or the wave action.

Records of sea chanties might be borrowed from the library. Some Hawaiian songs have a sea theme.

Sand.

Beach sand is nice to walk on, get buried in, pile up into mounds, build into sand castles, dig into, and lie on to make a "butterfly." It can be sifted, sorted, examined, and enjoyed.

Water.

Surfers try to catch a wave. Beach walkers can see if a wave can catch them. Waves that break on a sandy shore run up onto the beach in foamy ripples, becoming the opponent in a game of tag.

Sea Crafts and Sea Safety.

The City and County Department of Parks, Division of Ocean Recreation, holds classes and workshops in which various crafts are taught both to teachers and students. Instructions are given for such things as knot tying, net making, ancient Hawaiian navigational star chart making, crafting of paper boats which sail on water, making of driftwood outrigger canoes, and many other skills.

Classes in swimming and water safety for both beginners and proficients are scheduled, including adult classes for those who wish to work for life saving certifications.

Confer with your nearest District Park personnel.

Murals.

A very long section of butcher paper stretched out on the grass on a field trip or on the classroom floor can be made into a mural depicting tide pool or beach life. The drawings can be done with felt pen, finger paint, glue for attaching shells, sand, sea weed, and other objects, or any other feasible medium.

* * * * * *

A bibliography of songs, stories, and poems about the sea has not been listed in this topic. It can become difficult and time consuming for a teacher to track down specifically recommended pieces, whereas those which are already on the library shelf can serve just as well. If the school library has a paucity of sea literature, perhaps this could be rectified at the next book ordering season with the help of recommended children's book lists which all librarians have at their disposal.

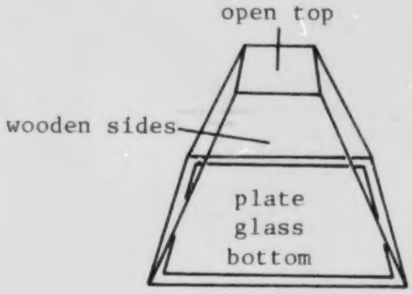
7. LOOK BOXES

A look box, for a youngster trying to peer into a tide pool, is a device which gives a clear window to the world beneath the surface without interference of rolling waves and surface ripples.

A look box is any open container with a transparent bottom. The sides of the container prevent water from sloshing over the top of the viewing window.

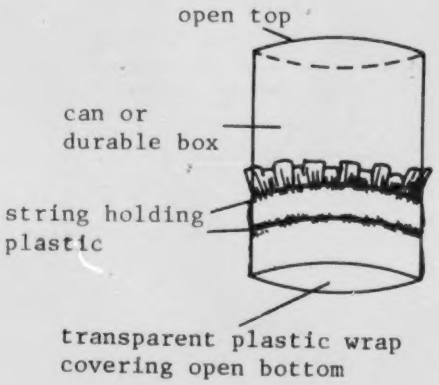
Science Laboratory Look Box.

Standard "professional" look boxes usually have a large square bottom of plate glass. Sealed to the glass are four wooden sides in the shape of a truncated pyramid. A small square at the top is open for peering in.


open top
wooden sides
plate glass bottom

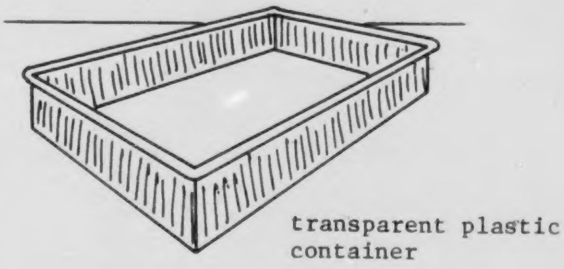
Tin Can Look Box.

A good-for-one-time-usage-only look box is a #10 can (or any similar durable container), open at top and bottom. Over the open bottom is stretched a film of transparent plastic wrap such as that used for covering food dishes. The film is held firmly in place by rubber bands or string. On a field trip, bring along a roll of plastic wrap to renew windows broken during work in the water.


open top
can or durable box
string holding plastic
transparent plastic wrap covering open bottom

Refrigerator Dish Look Box.

A look box reuseable several times (until someone cracks it) is a transparent plastic refrigerator food storage container or a plastic shoe box. Buy the kind without ridges or decoration on the bottom.


transparent plastic container

Gallon Jug Look Box.

A look box that is relatively durable, inexpensive, and easy to construct consists of a plastic gallon jug with the bottom cut out and a half petri dish sealed into the hole. Half the top is cut away for viewing, leaving the handle intact for holding.

Construction of a Gallon Jug Look Box:

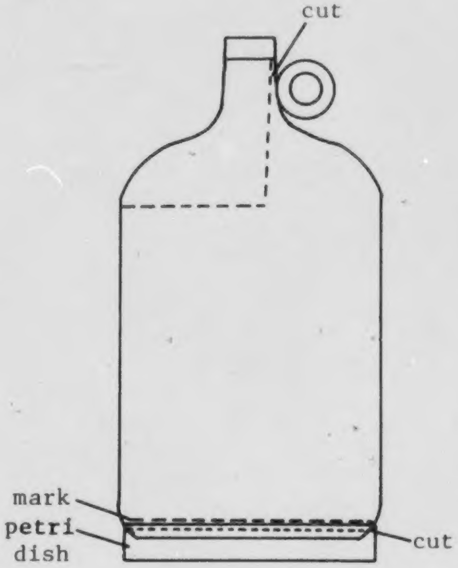
Materials.

- *Gallon plastic jug, 1 per student or pair of students*
- *Silicone sealant, 1 tube for about a dozen look boxes*
- *Plastic disposable petri dishes, size 150 mm x 15 mm. Half dish per look box (see below for source of purchase)*

Procedures.

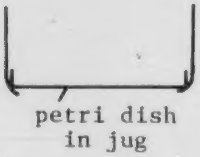
1. Using a scissors, hack saw, and/or sharp blade, cut away half the top of a plastic gallon jug, leaving the handle as shown in the diagram.

2. Set the jug on top of an open half of a petri dish. Make a mark around the jug at the top rim of the petri dish. Cut the bottom out of the jug about ⅛ inch below or inside the mark, so that the hole in the bottom of the jug will be slightly smaller than the dish.

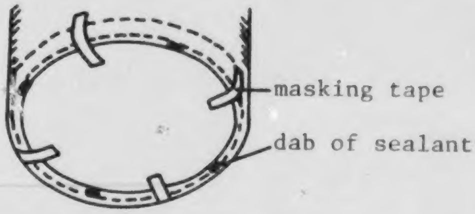


3. Place the half petri dish inside the jug at the bottom. Hold it in place with masking or Scotch tape.

4. Apply small dabs of sealant at three or four spots around the edge to secure the position of the half petri dish in the jug. Let set for about an hour or until it becomes firm. Then remove the masking tape.



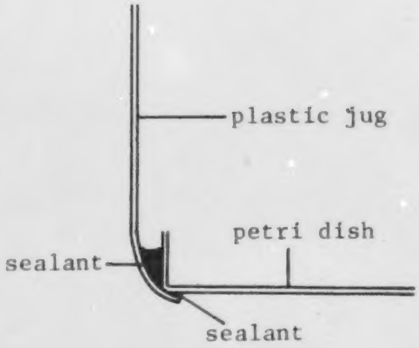
Having the dish held firmly in place at the three or four points prevents the dish from moving or slipping when sealant is applied later. If the dish is not held firm, it slips and smears sealant across the face of the dish, obscuring the clearness of the window. Avoid touching the



window with sticky fingers for the same reason.

5. With the dish held firmly by the dabs of sealant, lay a ribbon of sealant all around the crack between the half petri dish and the jug, both inside and outside, smoothing it into the crevices. Carefully avoid smearing the window.

6. Allow to cure for 24 to 48 hours.



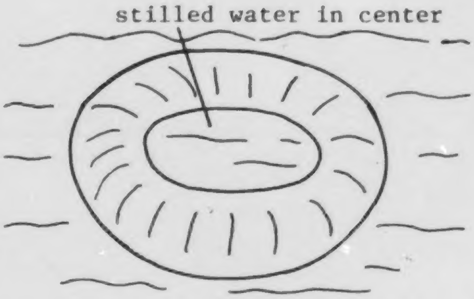
Plastic disposable petri dishes, 150 mm x 15 mm, are sold in lots of 100 dishes by Van Waters and Rogers (VWR), in lots of 10 by X-Ray and Medical Equipment, Inc., 3160 Ualena Street, Honolulu, Hawaii 96819. The 1976 retail price was $20.00 per box of 100 covered dishes, which comes to 10¢ per half dish. The top half of the dish is clear and makes a clear window in the bottom of the look box. The bottom half of the dish is scored in one-cm squares and provides built-in quadrats for making rough population counts.

Since the petri dishes are sold in lots of 100 per box, economy dictates finding fellow teachers with whom to share the purchase of the 200 half petri dishes. This might be done at teachers' meetings and workshops, or by advertising through the elementary teachers section of the Hawaii Science Teachers' Association. Not all the petri dishes need to be made into look boxes. Plastic petri dishes make good insect cages, small animal food dishes, saucers for potted plants, sorting boxes for pins and paper clips, pans for small hermit crabs - the uses are almost endless.

The idea for construction of the gallon jug look box evolved during development of the Hawaii Marine Studies Science Project and the Hawaii Nature Study Project at the Curriculum Research and Development Group, University of Hawaii.

Substitutes for Look Boxes.

An inflated innertube, a bicycle tire, or any large floating ring on the water interrupts surface waves and creates a quiescent surface inside the circle. Although this does not eliminate the effects of refraction and reflection of light, the smooth surface water can be seen through with relative ease.



Inflated Inner Tube

8. SALT WATER AQUARIA

Introduction.

Aquaria of different kinds serve different purposes, ranging from big, beautiful, display tanks and large, less-beautiful "working" tanks, down to temporary gallon-jars and simple flat pans.

A classroom marine aquarium is a powerful stimulator of student interest in marine life. Even if no experimental work is done, the mere presence of a tank works as an educative factor. In classrooms where a marine tank is maintained students soon progress from looking into the tank to taking over its care, especially after watching their teacher do this for a while.

For more serious study, marine aquaria aid in making close-up observations of reef and tide pool organisms, they provide opportunities for careful study of feeding and behavior patterns. Many marine related classroom activities depend upon the maintenance of a salt water aquarium for collecting long term data.

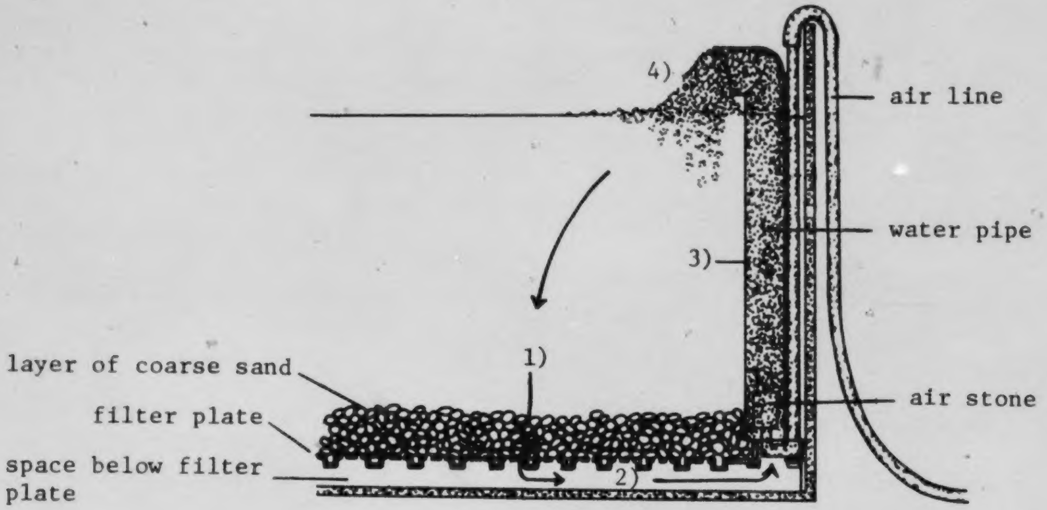
In the presentation of this topic below, filtration/aeration processes are discussed first, since the functioning of these systems is basic to the assembly and operation of a tank. Secondly, different sizes and types of tanks are described. Finally, some hints are listed on stocking and maintaining aquaria for different purposes and different kinds of organisms.

Filtration/Aeration Systems.

Life on land, like life in the sea, requires free oxygen and a nonpolluted environment in which to live. A good filtration/aeration system in an aquarium takes care of both oxygen supply and waste disposal. A number of different filtration/aeration systems can be used.

-UNDERGRAVEL FILTERS. Filtration through sand or gravel is the most effecient and the most fail-safe system to use. An undergravel or subsand filter consists of a perforated platform placed about a half inch above the bottom of the tank, supporting about a two-inch layer of coarse sand. A water pipe is located at one end or at each end of the tank. An airstone is placed in the bottom of the water pipe. Air entering the bottom of the pipe escapes upward, dragging water with it. This sets up water circulation in the tank, i.e. water in the tank filters through the sand into the space below the filter plate, flows over to the water pipe, is lifted up through the pipe by the air flow and spills back into the tank again.

Oxygen is added to the water by bubbling action at the top surface produced by the rising stream of air bubbles. The vigor with which air enters the airlines and the tank is regulated by inserting adjustable valves. Gang valves connected into air hoses are usually hung on the outside of a tank.



1) Water drawn down through filter.
2) Water flows over to pipe.
3) Water lifted by air.
4) Water spilled back into tank.

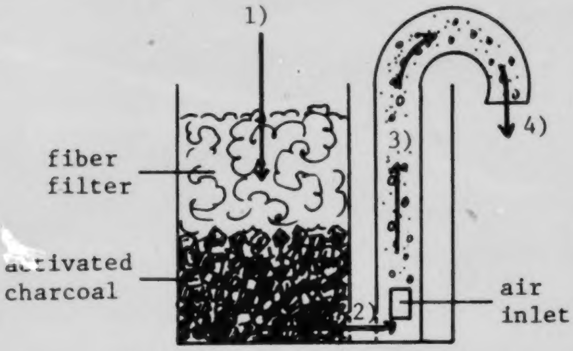
Waste products are removed as the water is filtered downward through the sand bed. The efficiency of the sand bed depends on a build-up of decomposing microorganisms in the interstices of the sand. A mixture of coarse and less-coarse sand provides the best variety of interstices. Avoid fine grained sand which can drop through the pores of the filter plate or become densely compacted. Nitrifying bacteria and other microorganisms live in the interstices and in a film which develops around each sand grain. The organisms extract waste products and decaying matter from the water as it filters through the sand.

A newly constructed aquarium with a "clean" layer of sand needs a week or two to build up a bacterial population in the interstices before it reaches maximum filtering efficiency. This is called conditioning or seasoning the tank. Putting a few hermit crabs or similar hardy animals in a new tank adds ammonia (urine) into the sand, thereby hastening the build-up of microorganisms. The crabs are hardy enough to withstand the not yet balanced tank conditions.

-CORNER FILTERS, OUTSIDE FILTERS. Plastic containers, often triangular in shape fit into an inside corner of a tank. Flat, rectangular containers may be hooked to the outside of a tank. Both operate on the same principle.

A siphon is set up between tank and top of an outside container. No siphon is needed if the container is inside the tank. Either by siphon leading to the outside container or by holes in the inside container, water comes into the top of the filter box. The water moves down through a layer of cotton wool or polyester fiber, then through a layer of activated charcoal. The wool filters out gross particles. The charcoal adsorbs noxious gases. The filtered water at the bottom of the container enters a water pipe and is propelled upward and back into the tank by air bubbles.

Before placing new charcoal in the filter, rinse the charcoal thoroughly in running tap water. This removes fine charcoal dust which otherwise spills into the tank water and blackens it.



1) Tank water goes into box and filters through fiber and charcoal.

2) Filtered water moves over to water pipe.

3) Water pulled up by air.

4) Water returned to tank.

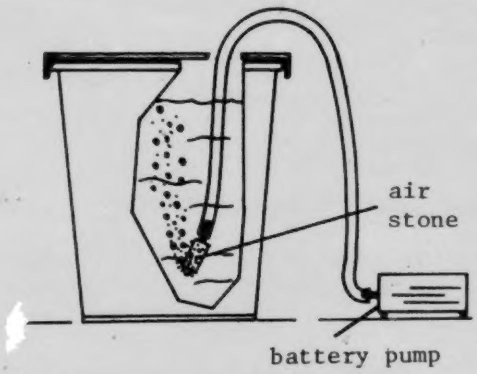
-AIR STONES AND SPRAYS. Bubbling air into water introduces free oxygen which all animals need. Free oxygen also partially cleans water by oxidizing some waste materials.

Placing an air stone in a small tank or gallon jar provides a temporary life support system. This is effective until waste products get ahead of the limited capabilities of an air stone.

Battery operated pumps with an air stone can be hung on the side of a collecting bucket to keep air bubbling through the water while animals are transported from oceanside to classroom.

An air stone hanging in a brine shrimp hatchery keeps young shrimp sufficiently aerated and agitated for successful growth.

Another way to mix oxygen with water is to spray water into air. This is the purification system used as one step in some sewage treatment plants. This is also the system used in nature when water is oxygenated and purified by being tumbled over water falls or rapids in a river or by breaking ocean waves.



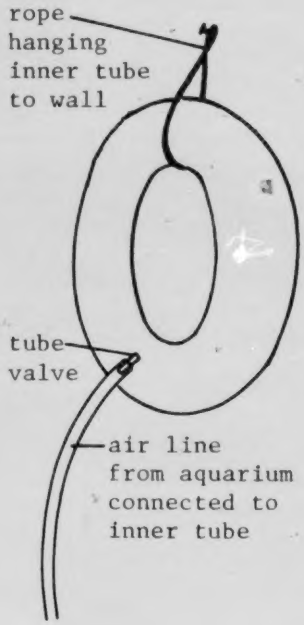
Covered Bucket
for Transporting Animals

-AIR FROM AN INNER TUBE. An inexpensive, silent, and entirely adequate way to aerate a tank involves use of a tire inner tube.

Inflate a large inner tube with a bicycle pump. Attach an aquarium air hose to the valve and adjust to allow a slow release of air. Place the inner tube behind or under the classroom aquarium with the airline directed into the aquarium filter system.

Four to six hours per day of aeration from the inner tube is sufficient. In fact the reason most aquarium pumps are operated on a continuous 24-hour schedule is convenience in not having to turn them on and off.

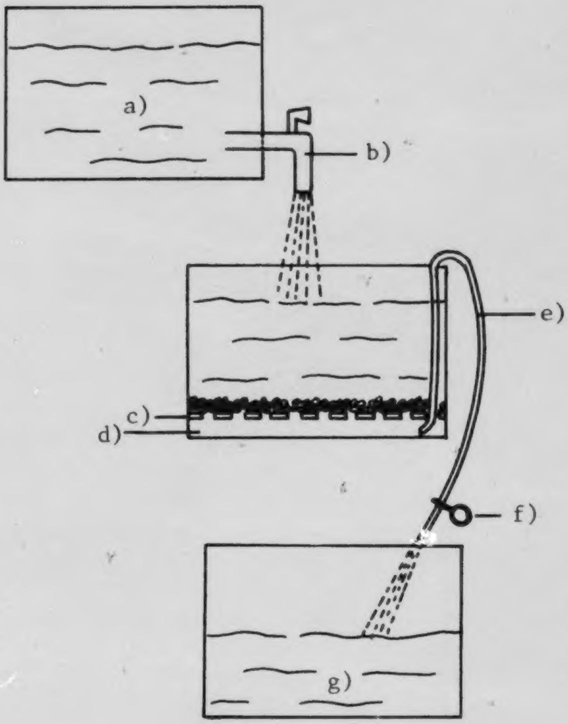
Aeration by inner tube is the invention of Rev. Leonard Hacker, S.J., for use in schools in the Marshall Islands.


rope hanging inner tube to wall
tube valve
air line from aquarium connected to inner tube

-SHALLOW WATER. The lazy man's way to aerate water is simply to keep it exceedingly shallow. Sea water no deeper than one inch in a flat pan has sufficient surface area compared to depth to provide adequate oxygen exchange between the water and the atmosphere above it. For short experiments, a pan of hardy tide pool animals covered by an inch of sea water can be maintained without air stone or filter. There are some limitations to this system. Waste products can build up so that the water may need to be renewed periodically. Also, evaporation from the broad surface alters salinity levels. This can be countered by adding tap water to maintain the inch depth, or by once- or twice-weekly renewal with clean sea water.

-CYCLING OF SEA WATER. Oceanariums and research stations located at oceanside usually cycle sea water in and out of their institutional tanks directly from the ocean. "New", clean ocean water is pumped into the tanks while an outlet from another part of the tank returns the "old" water to the ocean.

Schools with campuses adjacent to the ocean can set up a direct cycling system scaled down from the commercial model. This involves setting up a sea water holding tank above an aquarium and an overflow tank below it, all three tanks connected by siphons.



a) Ocean water holding tank.

b) Spigot regulating a fine spray, or fast drip, of water into aquarium.

c) Subsand filter.

d) Space below filter plate.

e) Siphon going from bottom of aquarium to overflow tank.

f) Clamp to regulate outflow spray to match inflow at b).

g) Overflow tank.

The system operates by having students bring in buckets of new ocean water as needed to keep the holding tank filled. Used sea water from the bottom tank can be discarded or partially re-used by pouring it back into the top tank. The water is aerated by using a fine spray in moving water from tank to tank - at b) and f). The water is also filtered through the sand bed. Thus the "old" water going into the overflow tank below is in all likelihood in good condition and can be re-used by dumping it back into the top tank along with a smaller addition of newly brought in sea water. This reduces the labor of bringing in a full quantity of new sea water each time. Tests can be run to see how often "turnover" of new ocean water is needed for the number and types of animals in the tank.

The advantages of this system are: It is an effective and efficient system. It operates without need of electricity, pump, or airlines (which means it conserves energy). By regulating the inlet/outlet clamps, high and low tides can be simulated. The simplicity of this system allows much flexibility for doing various experiments, e.g. the holding tank can be used for animals which can survive in used sea water.

Students can take pride in their energy-saving system which emulates commercial systems.

-PLANTS IN WATER. In fresh water aquaria, water plants play a significant role in keeping water oxygenated. Plants also supply food for plant-eating fish and snails.

This is not the case with sea weeds in a marine tank. Sea weeds seldom "earn their keep" as oxygenators. They do serve as food material for grazers in which case they need to be resupplied into the tank as they are eaten. Their presence provides hiding places and completes the habitat. Sea weeds are also decorative in a tank as long as they are kept pruned of dead branches.

Types and Sizes of Tanks.

The quickest and easiest way to acquire a good salt tank is to buy one, together with all needed parts and pump. See any standard laboratory equipment catalog, or visit your local pet shop. Make sure that the tank is constructed for salt water, meaning it must have no metal parts in contact with the sea water.

The recommended size for a salt water aquarium for classroom use is 15 to 20 gallons. Smaller than that does not allow for variety and good balance of reef invertebrates. For more tank space, multiply the number of tanks rather than increase the size of one tank, unless a large tank is needed for special purposes. In general, two 20-gallon tanks can house more animals and provide more ecological niches than one 40-gallon aquarium. Also with two tanks, if one becomes contaminated the other can still be used.

Classroom space can be conserved by having only one, or perhaps two, tanks, and re-using these throughout the year, running experiments in sequences one after another.

To reduce costs, a classroom aquarium can be teacher and student built from used glass at about half the purchase price of a similar-sized commercial tank.

Very inexpensive, but useful, aquaria can be made by lining a sturdy box with heavy-duty plastic such as the kind used for shower curtains or tarps.

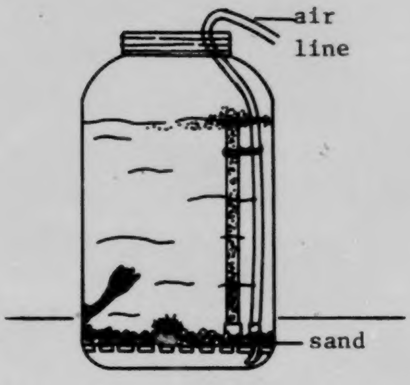
For short-term experiments with one or a few small animals, gallon glass jars and flat pans can be used. Plastic dishpans will also work.

Construction and maintenance of these smaller and home-made aquaria are detailed below.

Gallon Jar Aquaria.

Gallon jar aquaria are simple, easy, and adequate habitats for small fish and sea animals during a few days or weeks during which the animals are under study before being returned to the sea.

Each group of students might maintain its own gallon jar and give close attention to the animal under study.



A gallon jar aquarium will support only one or a few small animals such as one or two brittle stars, or a small sea cucumber, or a few small invertebrates. Gallon jars are not adequate for studying relationships among several kinds of animals nor for setting up a balanced system.

For aeration, most pet shops sell round, four-inch diameter, subsand filters which fit the bottom of a gallon glass jar. These can be covered by an inch or two of coarse sand or pebbles and hooked up to an external pump. An alternate to the subsand filter is to hang an air stone into the bottom part of the gallon jar.

A gallon size tank is fouled in short order by the death of one animal, one overfeeding, loss of water by evaporation, and small events which could be absorbed and balanced off in a large tank. The easiest care and cure all in small systems is simply to discard all the water about once or twice a week, or whenever murkiness or fouling is evident, and replace with a gallon of clean sea water. Before changing the water, let the new water stand next to the gallon jar for half an hour so that both the jars reach approximately the same temperature. Animals should not be plunged into water which varies more than a very few degrees from their previous environment.

On days between water changes be careful not to overfeed.

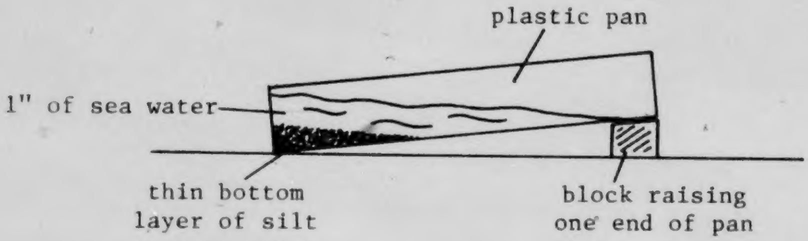
Keep gallon jar aquaria out of direct sunlight. Sun may quickly overheat a gallon of water. Generally speaking, direct sunlight is not beneficial and sometimes harmful, to sea animals.

Shallow Pan "Tanks".

Very small tide pool animals can be adequately maintained for a short time (a few weeks) in shallow, non-metal pans such as a plastic shoe box, plastic dish pan, a flat glass baking dish, a flat porcelain-coated pan.

Shallow pan tanks have many practical and varied uses. Hermit crabs, chitons, tiny marine worms, and other very small tide pool animals survive nicely in these shallow "tanks." Several pans may be maintained around the classroom to provide variety and maximum observational opportunities. At the end of the experiment after a week or several weeks, return the animals to the tide pool or ocean. See topics later in this book for experiments using shallow pan tanks.

Shallow water in a flat pan receives enough oxygen from the exposed surface to keep from fouling. No filter or air stone is needed. The bottom of the pan may be covered by a thin layer of sand or tide pool silt in which tiny marine worms may tunnel. Some aquarists tilt the pan so that the upper end of the flat bottom is nearly out of water while the lower end has about ½ inch of sand or silt covered by about one inch of sea water.



Snails tend to crawl over the top edge of the pan. To keep them confined, smear a bead of petroleum jelly around the top edge, or cover the pan with a piece of screening, or slip the entire pan into a nylon stocking.

The predominant difficulty with shallow pan "tanks" is rapid evaporation of water from the surface and the consequent build-up of salinity. To offset this, mark the depth of sea water on the side when first setting up the pan. Add tap water daily to keep the water up to the marked level. Although most tide pool animals can tolerate wide fluctuations in salinity, weekend desiccation may exceed their limits. Over weekends or holidays place a piece of glass or a board over the top of the pan to retard evaporation. Leave a small slit opening at one or both ends for oxygen exchange.

Wading Pool Tanks.

An aquarium of heroic proportions can be made by inflating a child's plastic wading pool of several feet diameter and installing it on the classroom lania. It can be filled with sea water to become a replica of a tide pool, a portion of reef flat, or a turtle pond.

Wading pool tanks are sufficiently shallow not to require special aeration but must be watched for buildup of excessive salinity. Crabs with claws big enough to pierce the plastic sheeting may need to be eliminated.

Plastic Lined Box Aquarium.*

This is a money saver for classrooms having a lanai, a shaded outdoor area, or an indoor area which is exceptionally bright. Since the sides in this type of aquarium are opaque, the entrance of light is limited to the upper surface. Plastic lined box aquaria are more successful if kept low (under 10 inches) in comparison to width and length. This allows light to diffuse throughout the tank and also reduces pressure on the sides of the box.

---

*Adapted from the high school Marine Science Course developed at the Curriculum Research and Development Group, University of Hawaii.

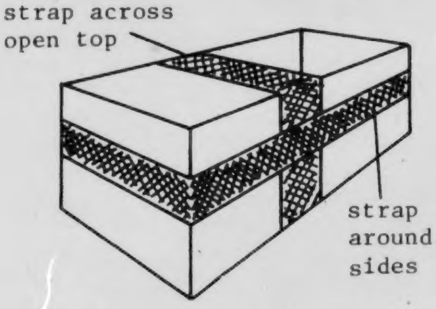
Materials for Making Plastic Lined Box Aquarium.

- *Strong cardboard box (such as fruit box or box in which meat is packed for shipping)*
- *Lawn-chair webbing, or strapping tape, or rope for reinforcement*
- *An alternative to a cardboard box is a wooden crate or five pieces of plywood strongly bolted together to make a box of desired size*
- *A sheet of heavy plastic such as a shower curtain, plastic table cover, or tarpaulin used by painters to cover furniture*
- *An alternative to plastic sheeting is two coats of fiberglass resin on the inner surface of a tight wooden box*
- *Decorative materials for outside the box*
- *A subsand filter, a corner filter, or an outside filter*
- *Airlines, valve, pump*
- *Coarse sand*

Procedures using Cardboard Box.

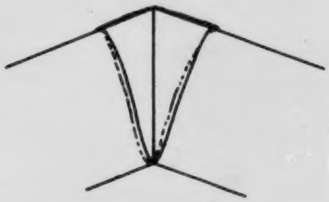
1. Obtain a substantial cardboard box. Use flat, lawnchair webbing, strapping tape, or rope to reinforce the sides. Place one strap over the top to restrain the long side of the box from bulging.

   If the box is well reinforced, small windows may be cut into the sides.



2. If transparent plastic is to be used, paint the inner surface white or line the box with white or light colored paper so as to reflect as much light as possible.

3. Place plastic sheeting in the box. Carefully fold the sheeting into the corners so that the box, not the sheeting, will support the weight of the water. Make sure all edges of the plastic reach up to the top edge of the box.



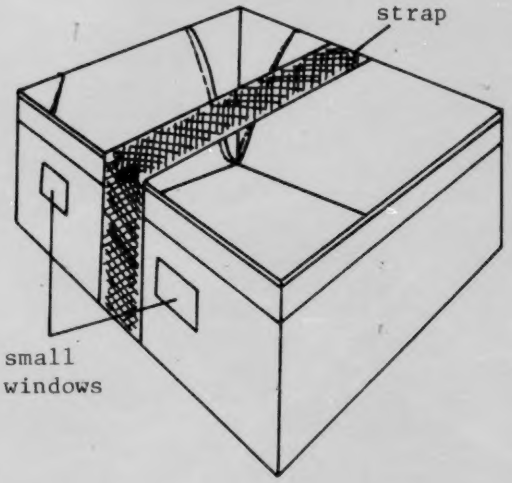
Plastic sheeting folded snugly into corners with all edges extending up over top.

4. Anchor the plastic sheeting around the top edge of the box with more strapping tape or any secure method.

5. Decorate the outside by painting, covering with paper, or with colored plastic.

6. Install the filter, airlines, and pump. If a subsand filter is used, make sure its sharp corners are situated so that they will not bore a hole through the plastic.

7. Place the box in its final position on a strong, flat supporting surface before putting in the sea water.



Finished and decorated aquarium

8. In placing rocks or sharp objects the tank, remember that plastic can be pierced and will then leak. Keep rocks and coral away from the sides.

9. If a leak occurs, take everything apart, dry out the plastic sheet, and mend the hole with plastic mender or epoxy resin.

Procedures using a Wooden Box.

1. Secure a wooden crate, or make one using plywood or other smooth lumber. Keep in mind that light will be able to enter only from the top, so a low box is better than a tall one. The shape of the box may also be determined by the size and shape of an undergarvel filter, if that is what will be used. A very long, wide, shallow box can be constructed as a means of getting maximum surface for air and light as well as ample floor expanse for crawling animals.

2. Sandpaper the inside of the box. Go over the entire inside carefully to make certain there are no rough areas or bumps which could work a hole into the plastic sheeting when the water presses against the inside.

3. Cut one or more small windows in the side of the box, if desired, and sandpaper the edges to smoothness.

4. Paint the inside of the box white or a light color if transparent plastic sheeting is to be used.

5. Place plastic sheeting in the box, carefully folding it snugly into all corners so the box and not the sheeting will support the weight of the water.

6. Anchor the plastic sheeting around the top edge of the box, anchoring it firmly and neatly with strapping tape or by any suitable method.

7. Paint or decorate the outside of the box as desired.

8. Install the filter, airlines, pump, and coarse sand.

9. Place the aquarium in its permanent position on a well supported flat surface. Add sea water.

An alternative to lining the wooden box with plastic sheeting is to finish the smooth inside surface with two coats of fiberglass, following the instructions on the fiberglass can. Since fiberglass is transparent, the inside of the box might be painted white or a light color or decorated with picutres before coating with fiberglass.

How to Make an Aquarium from Used Glass.

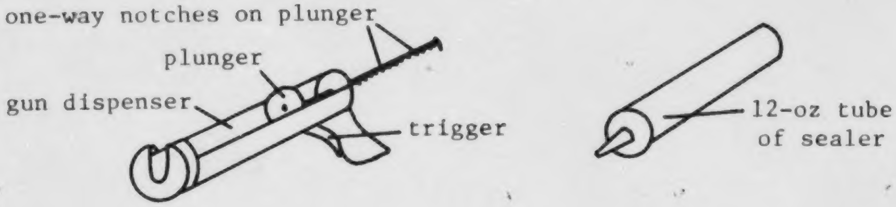
The source of the following instructions is Mr. Ronald Flegal whose generosity in working with teachers has brought marine life into many classrooms.

Materials.

- *Used plate glass cut to specified sizes (see below for sources and measurements)*
- *Clear sealant (see below for type and amount)*
- *Masking tape to hold glass in position until sealant is cured*
- *Razor blade to remove excess sealant from glass*
- *Undergravel (or other type) filter system*
- *Coarse sand or gravel*
- *Pump, airline, valves*

Used plate glass, which is less expensive than new glass, are panes that have been salvaged from building destruction. To obtain used glass, consult the yellow pages of the telephone directory, e.g. Fuller-O'Brien and others. For a 20-gallon tank, use plate glass which is at least ¼ inch thick.

Clear sealant is a plastic silicone product sold under various trade names such as Silastic, or Silicone Seal. A large (12-oz) tube is needed for a 20-gallon tank. Plastic sealants form exceedingly strong joints at edges and corners of glass. A ribbon or bead of uniform width can be more easily extruded if the tube is inserted into a caulking gun. A plunger is advanced by hand, pushing out sealant in a steady viscous flow.



DISPENSER GUN FOR SEALANT

Procedures.

1. Design the tank.

   An important consideration in construction design is the size of the undergravel filter plates. Since several types are available, it is wise to purchase a filter system which gives the desired bottom area, and then design the tank around its measurements.

   Also to be kept in mind is that a column of water 18 inches high exerts a tremendous amount of pressure on glass walls. A tank taller than 18 inches may be subject to sufficient force to weaken or break the seal of ¼-inch plate glass.

2. Calculate measurements of tank parts and order glass.

   The following measurements and diagrams show the calculations involved in planning a 20-gallon tank, low type, as an example of how any similar tank might be constructed.

Suppose that two filter plates fitted together have the overall dimensions of 29" x 11.5". The dimensions of the glass needed for construction will be:

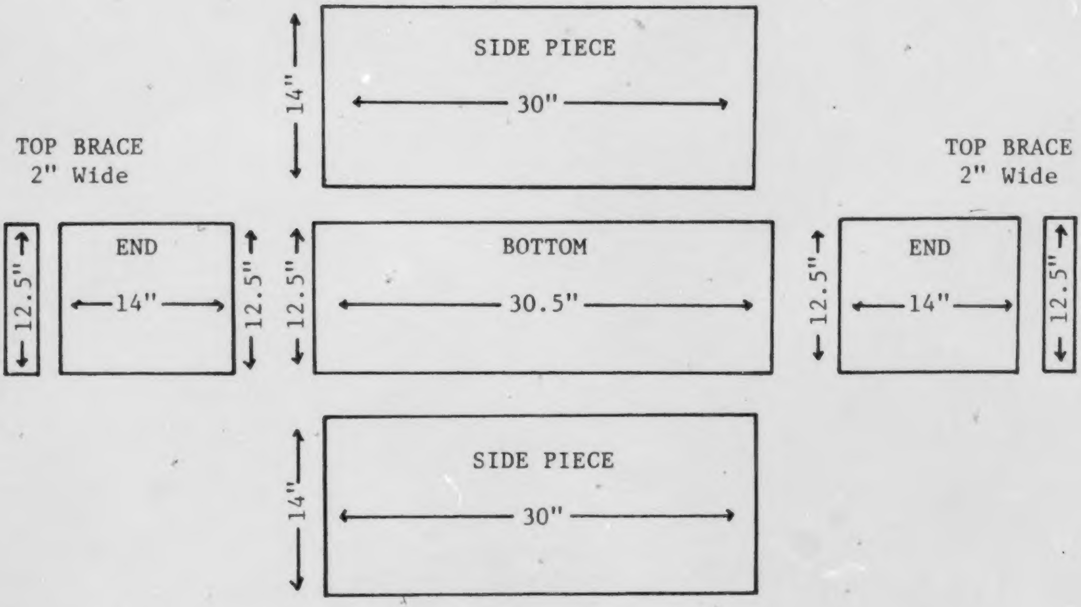
Bottom Piece: 30.5" long (to accommodate 29" length of filter plates plus ¼" thickness of two end pieces plus moving space).

12.5" wide (to accommodate 11.5" width of filter plus ¼" thickness of two side pieces plus moving space).

Two End Pieces: 12.5" wide and 14" high.

Two Side Pieces: 30" long (to fit between the two ends) and 14" high.

Two Top Braces (optional): 2" wide and 12.5" long.


SIDE PIECE
14"
30"
TOP BRACE
2" Wide
TOP BRACE
2" Wide
12.5"
END
14"
12.5"
12.5"
BOTTOM
30.5"
12.5"
END
14"
12.5"
SIDE PIECE
14"
30"

GLASS COMPONENTS OF 20-GALLON TANK

Computing Capacity in Gallons: One gallon = 231 cubic inches. The finished inside measurements of the above tank are 30" x 12" x 14" high. By filling the tank to a depth of 13", the water capacity becomes:

$$\frac{30'' \times 12'' \times 13''}{231} = 20.3 \text{ gallons}$$

3. Construct the tank.

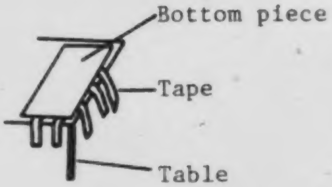
Cover a sturdy work bench with butcher or newspaper.

Place bottom piece of glass near the edges of the covered table.

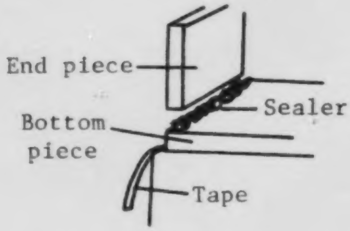
Put several long strips of masking tape on the bottom of the glass so that they hang over on one end and one side.

Put down a ribbon of sealer on the end edge of the bottom plate.

Join the edge of the end piece to the bottom piece and have a helper hold the end piece in place.

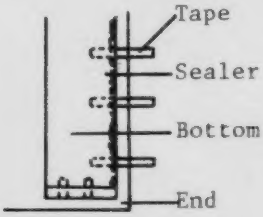

Bottom piece
Tape
Table

Bottom piece on a covered table

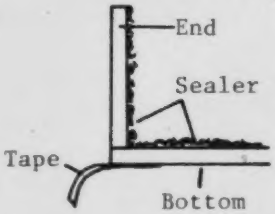

End piece
Sealer
Bottom piece
Tape

Joining end and bottom pieces

Put sealer on the lateral edge on the bottom piece and up the side of the end piece as shown below.

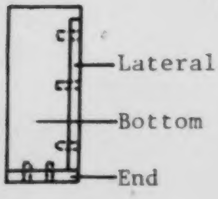

Tape
Sealer
Bottom
End

Top View - Sealer for laterals

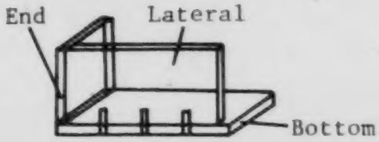

End
Sealer
Tape
Bottom

Side View - Seal for lateral pieces

Join lateral pieces to the bottom and end pieces. Have another helper hold this second piece in place (see below).


Lateral
Bottom
End

Top view of three joined pieces


End
Lateral
Bottom

Side view of three joined pieces

Have helpers hold plates steady and in a 90° vertical position for five minutes or until sealer "skins."

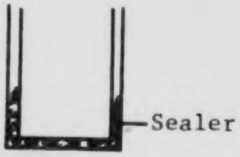
Now tape can be brought up to hold three pieces of glass in position.

Let the glass set for 24 hours.

After setting, excess sealer can be cleaned off with a razor blade.

Put masking tape on the bottom piece along the unjoined edges, and repeat the first day's process until the other two sides are in place. Let set for 24 hours, then reclean.

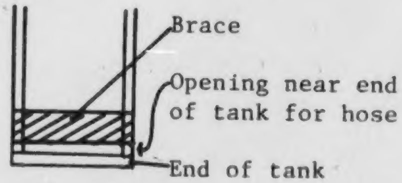
The braces should be as long as the width of your aquarium. The braces are sealed to the edges of the top of the aquarium to provide additional strength.



Top View - Sealer for brace

PRECAUTION: Make sure the braces are not so wide as to interfere with placing the undergravel filter plates or such items as coral heads, etc. in the aquarium.

In the case of very long aquaria, additional braces may be put across the middle making sure openings are left to accommodate equipment and specimens.



Top View - Placement of brace

Let the finished aquarium set for seven days for optimum binding of sealer and glass. The final clean-up can be done, the aquarium tested for leaks, and if all is well the filter plates, gravel, airline, and water can be added.

Obtaining Sea Water.

The most obvious source of sea water is the ocean which is within easy traveling distance of every school in the State of Hawaii. When collecting sea water, obtain it from as far away from the shore as possible because of shoreline dilution from fresh water run-off from the land as well as possible silt content or other pollutants.

Much of the bacterial and other microscopic life found in surface sea water can be eliminated by keeping the collected water in the dark or covered with a dark cloth for a few days before putting the water into the aquarium.

Schools on Oahu can obtain sterile sea water from the Waikiki Aquarium during working hours. Ask at the entrance desk from which you will be directed to the back where the water is dispensed free of charge. Bring your own containers. Waikiki Aquarium water is pumped from a chamber deep in the reef below the level of life, light, and oxygen penetration.

Artificial sea water can be made by buying bags of ocean water salts and following the directions on the package for mixing with tap water.

Stocking and Maintaining a Marine Aquarium.

Classroom aquaria in Hawaii are usually stocked by catching animals by hand in local tidal pools or reef areas. The number and types of animals in the tank changes as students find new animals or as the class becomes interested in new animals or experiments to try out.

Questions often arise concerning which kinds and how many animals can occupy the same tank at the same time. Some aquarists estimate that the carrying capacity of a marine tank is approximately three inches of fish per square foot of filter bed. Invertebrates are usually more flexible in their needs. Dr. Arthur Reed has developed his own rule which teachers in Hawaii have come to call Reed's Law. It is:

IF IT LIVES, KEEP IT. IF IT DIES, THROW IT OUT.

This is complemented by a second law which states:

IF IT ADJUSTS TO OTHER ANIMALS IN THE TANK, LET IT BE.

IF IT DESTROYS OTHER ANIMALS OR CAUSES DISRUPTION, TAKE IT BACK TO THE OCEAN.

Guided by these two working rules, teachers and students can go ahead and try as inhabitants of the classroom tank whatever they find in tide pools or reef flats. There are some basic hints, however, which can preclude the worst errors in this trial and error learning method. They are listed below, the more important ones in capitol letters.

- Use sea water collected from as far out on the reef as possible. Near shore water is more likely to be polluted or diluted with rain water.
- Start a new tank with a few crabs until the bottom sand has built up a good microorganism population and the tank has become conditioned, possibly in one or two weeks.

-PUT IN ONLY ONE NEW ANIMAL AT A TIME. With the addition of each new animal, (or a few new very small animals), allow a week or two for the habitat to adjust to a new balance.

-Although fish take the eye of beginning aquarists, invertebrates are the long-term winners for both interest and learning potential.

-Sea cucumbers can be treacherous. Save yourself the work of cleaning out the entire big tank by keeping sea cucumbers in their own smaller tank.

-DO NOT EXCEED THE CARRYING CAPACITY OF THE TANK. Overstocking with too many animals is the single greatest cause of failure.

-Provide some natural hiding places for the mobile animals.

-Include some scavengers for keeping the tank bottom clean.

-Notice what the animals eat. If they are plant-eaters, keep a sea weed grazing ground for them. If they are meat-eaters, they will eat bits of fish, brine shrimp, other protein food, and one another.

-Be prepared for cannibalism and war. The "Law of the Sea" is the same as the "Law of the Jungle."

-TOO MANY ANIMALS added into the tank TOO FAST spells disaster.

-Keep a hydrometer handy and test at least once per week for salinity. Add tap water if needed.

-If filter-feeding invertebrates are in the tank, add fresh sea water from time to time from which they can filter out microorganisms.

-Sea weeds and some animals such as anemones which contain chlorophyll bodies, require good daylight, not direct sunlight.

-The more light the tank receives, the faster the sides of the tank scum up with algae. Either add alga eating animals into the tank and/or reach in periodically with a razor blade or rough sponge and scrape down the inside of the glass.

Keep tanks out of the sun. On the other hand, classrooms equipped with wooden louvres put a tank in total darkness except during school hours which is insufficient to maintain chlorophyll beares. In these cases, a fluorescent light needs to be used to give several hours of additional light each day.

-As long as the water is clear and the animals thriving, the tank can continue on all year without renewal or changing of water.

-It is a good idea to take the tank down at the end of the school year, and clean everything thoroughly with clear water (NO SOAP). It can be reassembled as a new tank at the beginning of the new school year.

-If the water clouds and the tank fouls (usually because of OVERFEEDING, OVER STOCKING, and leaving in dead animal bodies), the whole tank has to be taken down and everything washed. In starting over, begin again with one animal at a time and DO NOT OVERFEED.

Other References.

Your "friendly neighborhood pet store" has a shelf of books about aquaria, fish, and aquarium advice. Select one or two for your classroom bookshelf. Many teachers consider aquarium books by Stephen Spotte to be the most helpful as well as the most authoritative.

The University of Hawaii Sea Grant Program has published a paperback ($1.75) entitled MARINE AND FRESHWATER AQUARIUM SYSTEMS FOR TROPICAL ANIMALS, by E. H. Chave and P. S. Lobel, April 1974. This booklet contains instructions for construction of a 100-gallon wooden tank and two smaller glass tanks as well as a plethora of information about tank maintenance and care of Hawaiian species of fish and other tank inhabitants.

Fish and Game Regulations.

In Hawaii, no special permit is needed for hand gathering or trapping reef animals. A permit is required for capturing animals by means of a net with mesh size smaller than 1½ inches. If it is anticipated that fine-mesh net fishing will be engaged in, call for a permit application at the office of:

Director
Division of Fish and Game
Department of Land and Natural Resources
1179 Punchbowl Street
Honolulu, Hawaii 96813

After obtaining the permit, a Fish and Game warden will visit your classroom tank for approval and check for the legality of your catches via a monthly report. Fine-mesh nets often pick up tiny silver fingerlings which are the young of ocean food fish and therefore illegal to capture. Clams and lobsters at certain seasons and of certain sizes are also illegal to catch.

All items, fish, invertebrates, plants, and even rocks, are not permitted to be taken from natural reserve areas, identifiable by posted signs at these sites.

9. SCIENTIFIC NOMENCLATURE

Scientific names which are often a bugbear to adults hold a peculiar fascination for children. They like to roll them off their tongues and show off their ability to use big words. Once they learn the word "eviscerate", sea cucumbers never again "spew out their insides." A monkey pod tree disappears as soon as the poetic sounding Samanea saman comes on the scene. Children would rather talk about Grapsidae than rock crabs.

Not so fascinating to elementary children, but of great importance to scientists, are the rules of grammar and punctuation which control scientific nomenclature. Some of these rules are reviewed here in the hope that young students can be persuaded, if they use scientific names at all, that they use them correctly.

Living things, like people, are designated by two names. This is called BINOMIAL NOMENCLATURE.

The first word is the group or GENUS to which the plant or animal belongs. The second word is the name of the particular type or SPECIES. Putting both words together gives the double scientific name, e.g. Aplysia juliana which is a common sea slug in Hawaii.

The GENUS is the general group to which the plant or animal belongs.

The singular is GENUS.
The plural is GENERA.
The adjective is GENERIC.

For example: one genus, several genera, the generic name.

Generic names are always spelled with a capitol letter.
A generic name is always underlined when the word is written or typed, e.g. Aplysia.
A generic name is put in italics when it is printed, e.g. *Aplysia*.

SPECIES refers to the special type of plant or animal.

The singular is SPECIES (not "specie" which means coins or money).
The plural is SPECIES.
The adjective is SPECIFIC.

For example: one species, several species, the specific name.

Specific names always begin with a lower case letter, even when the word is taken from a proper noun.
Specific names are always underlined or put into italics.
Specific names are always preceded by the name, or at least the initial, of the genus, e.g. Aplysia juliana, or *Aplysia juliana*, or A. juliana (if it is clear from a preceeding sentence that the A. stands for Aplysia.)

Reef Flat near Blowhole, Oahu · Photo by A. S. Reed

SECTION TWO: INVESTIGATIONS FOR STUDENTS

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	A Look to the Future	Inside Back Cover

The two puzzles here, and those later in the book, are for the entertainment of children who enjoy word games.

PUZZLE FOR YOUNG CHILDREN

Directions: Write the numbers 1 to 26 in a single long line. Write the letters of the alphabet under the numbers. Under 1 put A. Under 2 put B. Under 3 put, and so on to Z under 26.

The groups of numbers below represent words. Place the matching letter under each number. What does the finished verse say?

19 8 5   19 5 12 12 9   19 5 1   19 8 5 12 12 19

___ ___ ___   ___ ___ ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___ ___

2 25   20 8 5   19 5 1   19 8 15 18 5

___ ___   ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___

SAME PUZZLE, BUT HARDER

Directions: Each number below represents a letter of the alphabet. The groups of numbers represent words. Figure out which numbers represent which letters and complete the words. The finished verse is a familiar one. If you cannot get started, your teacher can give you a starting hint.

10 4 2   10 2 9 9 10   10 2 3   10 4 2 9 9 10

___ ___ ___   ___ ___ ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___ ___

14 20   11 4 2   10 2 3   10 4 18 7 2

___ ___   ___ ___ ___   ___ ___ ___   ___ ___ ___ ___ ___

(Starting hint: 4 is the letter H. Second hint: 9 is the letter L.

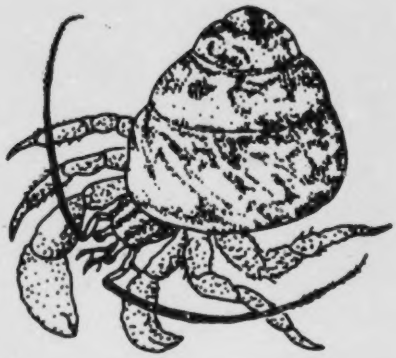
Answer: She sells sea shells by the sea shore).

1. HERMIT CRABS

Introduction.

Hermit crabs are lively and interesting inhabitants of the tide pools of Hawaii. Children of all three BAND levels can enjoy and do some worthwhile and simple experiments with them.

Hermit crabs are members of Phylum Arthropoda, Class Crustacea, along with crayfish, crabs, lobsters, and shrimp. Crabs and shrimp in general are treated in a later topic. Hermit crabs, because of their ubiquity, their special features, and their interest to children, is used as an introductory topic.



The several activities given here concerning hermit crabs may be pursued on field trips to the reef, or as classroom activities, preferably both. Besides the observations, there are a counting problem and a classification key intended to be challenging to older students.

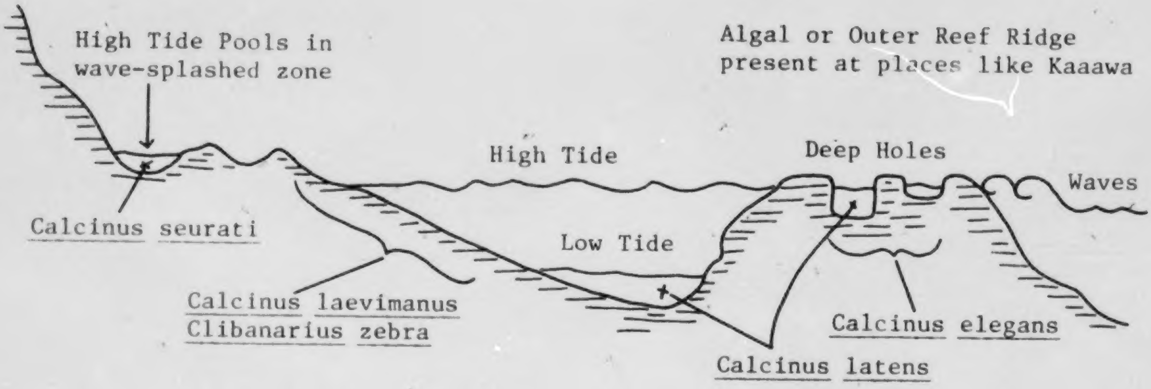
Hermit crabs are by no means an endangered species. The populations on most shorelines can support having a few specimens removed for class work. No more hermit crabs should be removed from the tide pools than are needed for planned observations and experiments, and these should be returned to the tidal area when the class work is complete. This is good conservation and is consistent with inculcating a respect for life.

Field Information.

Many hermit crabs live in the zone between high and low tide along the shoreline, occupying pockets of shallow water among the lava rocks. Different species of hermit crabs are found in different habitats as indicated in the diagram below. Only shallow water species are shown here.

Capture by hand or with a small dip net. Identification keys are on the last page of this topic.

CROSS-SECTION OF ROCKY SHORELINE


High Tide Pools in wave-splashed zone
Algal or Outer Reef Ridge present at places like Kaaawa
High Tide
Deep Holes
Waves
Calcinus seurati
Low Tide
Calcinus laevimanus
Clibanarius zebra
Calcinus elegans
Calcinus latens

Laboratory Maintenance.

Several hermit crabs can be kept in the classroom salt water tank. Allow enough space to permit the establishment of territorial rights among them. Also bear in mind that crabs are cannibalistic as well as likely to prey on other prize specimens in your tank. If classroom space permits, it would be instructive to have a different species in each tank.

For close-up student observation during the week or so of hermit crab work, maintain several "hermit crab pans" in working areas around the classroom. Students can glance at the crabs from time to time in between doing other lessons, as well as during hermit-crab-watching study or class periods.

A hermit crab pan is any flat, rust-proof pan (glass, porcelain, plastic) holding clean sea water not to exceed one to three inches in depth. At that shallow depth the water is kept sufficiently oxygenated without a pump or airstone by the large surface area exposed to the air. Mark the original water level on the side of the pan with grease pencil, tape or, something else that will stick. As water evaporates, refill the pan to its original depth by adding fresh tap water. It is difficult to keep control of salinity in flat pans where evaporation is rapid. For this reason, it is well to empty out all the old sea water at least once each week and refill with clean sea water.

For food, supply fish food and/or bits of scavenge material, especially recently-dead bits of mollusk or small pieces of frozen shrimp. Do not leave uneaten bits of food in the water longer than half an hour to prevent fouling of the water.

It may be necessary to fence the pan to keep the active hermits confined. Young hermit crabs require a supply of empty shells in increasing sizes into which they transfer as they grow.

Hermit Crab Investigations.

Problem 1. APPEARANCE AND BEHAVIOR (Field Work) BANDS 1, 2, 3

This first problem on hermit crabs suggests observations to be done at the beach during a field trip. For aids in arranging a field trip, see Section 1 of this book under that heading.

The aspects to be emphasized at the beach are the general habitat of hermit crabs, their behavior in natural circumstances, and a general acquaintance with the locale and other types of animals and plants which live in the same place. Both questions and answers can be quite general. Specific detail of anatomy and behavior can better be handled after crabs are brought back to the classroom where they can be observed more carefully.

The questions below must necessarily be adapted, cut back, or added to, depending on class level and field circumstances.

Problems:

What do hermit crabs look like?

In what kinds of places do hermit crabs live?

Who are their neighbors?

Does a hermit crab react to movement nearby or to shadows? (Check visual distance and direction.)

Do you think "hermit crab" is a good name for these animals? Why do you think so, or not think so?

Suggested Procedures.

Predetermine a good tide pool area for finding hermit crabs. Prepare the class for a Short Field Trip or make hermit-crab-watching part of the agenda on an Extended Field Trip (see Section 1 on Field Trips).

Most students can recognize a hermit crab. If they seem not to know what a hermit crab is, describe or show them one but let the details of description and behavior come from the students' own observations.

It is desirable to do as much observing as possible in the field so as to include observations of hermit crab habitat and environment. Questions used by the teacher can help to give focus to the observations and discussion. Some questions which you may find useful could be similar to these:

Do hermit crabs live in groups, or singly here and there?

Do they seem to live under rocks, on top of rocks, in crevices, in mud, on sand, in sea weed, or where?

What other animals live among them or near them?

Do they live in dark places, in the sun, in shade, where it is cool, or warm, or under water, or dry?

Do the hermit crabs seem to be all the same size and kind or do they vary greatly?

What are some of their general characteristics?

Are they very active, somewhat active, or do they mostly sit quietly?

How frightened or shy are they of human encroachment or do they pay no attention to your presence?

BAND 1 children make their "reports" by remarking, exclaiming, and showing delight with their hermit crabs. Older students can be expected to produce sketches and notes in notebook reports on hermit crab appearance and activities. See the PROGRAM MANUAL on student notebooks.

Problem 2. CLASSROOM OBSERVATIONS ON HERMIT CRAB BEHAVIOR BANDS 1, 2, 3

Presumably, the students have already gained a general knowledge of hermit crabs and their habitats from doing Problem 1 at the beach. Problem 2 proceeds with classroom close-up observations. In the event that a field trip could not be done, classroom observations can still be pursued, perhaps adding into the class discussion some of the questions and information from Problem 1 above which was missed in the field.

Materials.

- *"Hermit crab pans" (see Laboratory Maintenance above)*
- *Sea water*
- *Rags for mopping up spilled water*
- *Hand lenses (optional)*
- *Empty shells of various sizes*

Problems:

Movement:

How do hermit crabs move about? How do they use their legs and claws in walking?

Do they move fast or slow? Do they walk better or differently on different surfaces such as the smooth bottom of the pan, sand, pebbles, a cloth in the bottom of the pan, a sponge?

Do they move about in groups or independently of one another?

(cont'd on next page)

If they crawl to the edge of your desk, will they go on over or back off?

Can hermit crabs crawl up vertical surfaces such as a glass wall or steep rock?

How does a hermit crab react if its shell is touched or moved?

Does a hermit crab gradually become accustomed to movement or touching so that it seems less "afraid" after it becomes used to you?

Does the type of shell a hermit occupies influence its type or speed of movement?

Can you "race" hermit crabs on a track or from the center to the edge of a circular pan?

Housing:

The shell in which a hermit crab lives is sometimes called its "house".

Do hermit crabs grow their own houses or do they get them from some place?

Watch a hermit crab examine an empty shell.

Watch a hermit crab climb into a different shell. How does he do it?

Will a hermit crab go into a "house" which is not a sea shell?

Other Behavior:

What do your hermit crabs like best to eat?

How strong are they in holding onto a shell or other object?

What else do you notice about hermit crab behavior?

Think of some tests or experiments you can do with hermit crabs.

Suggested Procedures.

Set up several hermit crab pans around the classroom so that each group of students can observe hermit crab behavior not only during hermit-crab-watching time but also in between doing their other lessons. Provide each pan with several hermits and several additional empty shells of a slightly larger size than those in which the hermits are.

Hermit crabs do not seem to be at the top of the list for animal intelligence but they can be trained, more or less, to expect food in certain places or at certain hours or days.

In addition to the suggestions made by the problem questions, many students are quite resourceful in making up ideas of what to watch or test. Students in pilot classes have held hermit crab races and measured directions, speeds, and other movements. The following two items give the teacher aids on housing and stimulation of other observations.

1. Getting a hermit crab out of its house, and into another house.

Removing hermit crabs from their shells can be done by the teacher ahead of time and the de-housed hermits brought to class. Some teachers prefer to do this because of the occasional loss of a hermit crab in the process, an event which distresses some children. On the other hand, students are often adept at doing the dehousing job themselves.

The "hot foot" technique described here works better with thin-walled shells. Place the hermit crab on a wet sponge and hold it firmly in a position in which it can reach the sponge when it comes out. The wetness of the sponge serves as an additional lure to draw the crab out.

Touch a very hot nail or soldering iron or burning match to the tip of the spire of the shell. The heat drives the crab out of its shell promptly. Hold the shell very still during the process since a hermit crab is afraid of movement as much as, or more than, it is discomfited by heat. Movement of the shell may cause it to retreat back into the shell and burn its little behind.

One teacher successfully expelled hermit crabs by blowing a jet of air into the shell.

With one or more denuded crabs and a number of empty shells, many kinds of experiments can be done. For example:

> If two nude hermits are given only one shell between them, do they fight for the possession of the one shell?
>
> If one nude hermit is presented with a variety of empty shells, how does he go about choosing one to enter?
>
> Do hermits change shells readily when presented with shells of many shapes and sizes?

Most hermit crabs, even those already in a shell, will orient to and explore new shells, seeking one of a more desirable size. Help the students note the crab's exploring, tapping, and "measuring" of shells under investigation.

Two hermits in competition for the same shell interact ("fight"). Territorial or dominance fighting in animals of all species is seldom or never to the death or even to the drawing of blood. Fighting ceases as soon as one (the loser) shows a submissive stance to the winner. Can the students detect a "submissive posture" in losing hermit crabs?

2. Observation Aids for Younger Children.

Hermit crabs are lively little animals who can capture student attention unaided, especially when a hermit crab "fight" is in progress or when a hermit is changing its shell. But hermit crabs do not always cooperate by interacting or changing shells in harmony with the school schedule. So during those observing periods in which the hermits persist in doing nothing more than crawl around aimlessly, you might take up the slack in the waiting and watching process by one or more of the activities below.

a. Read a hermit crab story aloud.

PAGOO, by Holling Clancy Holling, 1957, Houghton Mifflin Company, Boston, is a beautiful piece of children's literature about a hermit crab told in personalized story form, incorporating accurate information about Pagurus. If the children can be settled quietly around their hermit crab pans to watch, you might read PAGOO to them aloud. For many young children, the story is too long for one sitting and needs to be divided into parts, or select only some sections for reading. Another way is to read the story privately yourself and then tell it to the children as a conversation of your own. For primary children, simply showing the pictures may be enough.

Another story is by Jane Castellanos, 1963, A SHELL FOR SAM, Vesna Borcic Golden Gate Junior Books, San Carlos, California. "2.75.

Your library may have other stories.

b. Develop a Continuous Group Story.

Start a "serial" story about hermit crabs. Each child adds one sentence to the story describing the appearance or behavior of the hermit crab he or she is observing at the moment. The "rules" of the game might be stated to the students something like this:

(1) Select a name for the hermit crab you are watching and refer to it by its name.
(2) Tell something about it.
(3) Raise your hand (or use some other method) when you have a sentence to add aloud to the story.

Here is a short sample from a continuous group story:

Student #1: "Herman is sleeping. He has his big white claw folded over his doorway so no one can see him."
Student #2: "Crabby is poking around the edge of the pan. He picks at every pebble as he goes."
Student #3: "Dumpy has an adventuring spirit. He is making his third try at getting out of the pan. Now he is yelling to his pals, 'Hey you guys! I think there is an opening over here.'"
Student #4: Etc.

c. Teach a Hermit Crab Action Song (to very young children).

Find a melody to fit the following words, or make up a simple tune.

Words for Song	Accompanying Actions
I am a little hermit crab Looking for a hermit shell.	-Fingers of one hand creep across desk or table.
I see one . . . Here I come!	-Cup the opposite hand a short distance in front of the creeping fingers.
This one suits me very well.	-The creeping fingers jump inside the cupped hand.

Problem 3. BODY PARTS OF HERMIT CRABS BANDS 1, 2, 3

The amount of detail gone into in this topic can range from the most casual and obvious observations with the young children to as much detail with the older students as they have the interest and capacity to learn.

Problems:

What are the body parts of a hermit crab?

What parts are visible when the crab is walking around in a shell?

What parts are always covered by the shell when the crab is walking around?

Make sketches from real life of a hermit crab completely in its shell, of a hermit crab extending out of its shell, and if possible of a hermit crab denuded of its shell.

Learn the names of some of the body parts.

Suggested Procedures.

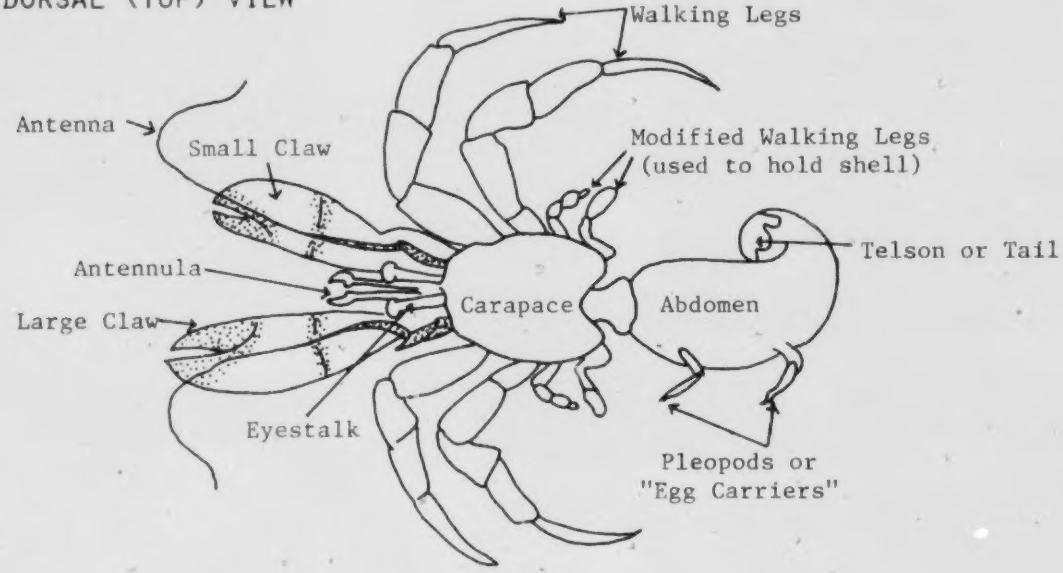
To allow sufficient viewing, this problem calls for one hermit crab per two or three students. Encourage the students to make their drawings at "eyeball to eyeball" level with the crab. "How does a hermit crab look to another hermit crab?"

While waiting for this lesson, the hermits could be maintained in the class tank or in holding pans. For sketching they can be taken out and held on damp cloths for brief intervals, then returned to the water.

The degree of precision, and the amount of vocabulary learned, will depend on the ability level and interest of the students.

The diagram below can be reproduced for the students or placed on the overhead projector screen after the students have done as much as they can without assistance.

DORSAL (TOP) VIEW


Walking Legs
Antenna
Small Claw
Modified Walking Legs (used to hold shell)
Telson or Tail
Antennula
Carapace
Abdomen
Large Claw
Eyestalk
Pleopods or "Egg Carriers"

In nearly all Hawaiian hermit crabs it is the left claw which is larger than the right. Diagrams and keys of hermit crabs prepared for use on the Mainland or elsewhere show the right claw as larger. Hawaiian hermit crabs are uniquely "southpaws."

Problem 4. TYPES OF SHELLS USED BY HERMIT CRABS BANDS 2, 3

This activity, which is better suited to older students, is best done at the beach along tide pool areas so as not to require collecting (and perhaps destroying) large numbers of hermit crabs.

Materials.

-Notebooks and clip boards for taking field data

Problems:

What kinds of shells do hermit crabs live in?

Make a list of types of shells occupied by hermit crabs.

Take a count of which types are most used.

Suggested Procedures.

Divide the work at the beach by teams and by tide pool areas. It is not necessary to know the scientific names of the shells, or even their common names. Simply note the general shape, structure, or "style" of shells used by hermits, or set up your own designations such as "Shell Type #1", "Shell Type #2", etc.

Counts might be taken by picking up shells containing hermit crabs one by one while a recorder notes down the shell type on a previously prepared data sheet fastened to a clip board. Another method is to remove all, or most of, the hermit crabs from a given tide pool and sort them into different pans according to shell type. Then count how many in each pan. When the count is finished, replace the crabs in the same tide pool.

Examine the data as a class and see what conclusions might be drawn.

Do the crabs show a strong preference for any one kind of shell?

Is their choice of shells seemingly random?

Do the statistics on shell type vary from pool to pool or are all the pools about the same?

Did any hermits choose non-shell houses? What kinds?

Do you think hermits seek shells of specific types or do they take whatever happens to be around? Why do you think so?

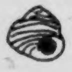
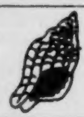
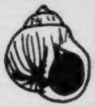
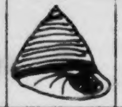
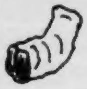
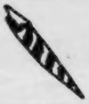
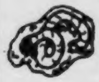
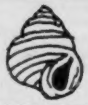
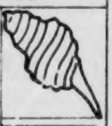
A written notebook report of the formal type is in order here for the older students. See the PROGRAM MANUAL on student reporting.

Sample of a Count Taken by a Laboratory School Class.

Below is a data table made by a class of 6th graders who were divided into six different groups at a field site. Their assignment was to take an inventory of the different kinds of houses occupied by hermit crabs. The students did not know the names of most of the shells, so they glued a sample shell to the top of each column on the class data sheet.

The class data sheet as it was developed by the students is reproduced below. The diagrams at the tops of the columns stand for the actual sample shells which were glued to the page. Note that the student-selected column headings are partially redundant and lack the refinements of logic which might be achieved by older students possessing a better knowledge of shell types.

TABLE 1. SHELL PREFERENCE OF HERMIT CRABS AT KAHALA BEACH

Student Group Number	Numbers of various types of shells occupied by hermit crabs								
									
1	4	54	17		37		14	3	
2		30	1	1	11	1	55	1	
3	14	130	15	3	40		125	3	1
4	6	85	3		9		72		
5	15	152		4	45		13	8	
6	12	41	3		5		20	1	
Total	51	492	39	8	147	1	299	15	1

Unfortunately, no record was kept of these students' conclusions drawn from the data. As an exercise in data analysis, you might reproduce the above data for your class and ask them to make an assessment of shell type distribution indicated by the data. They may wish to speculate on reasons for the distribution.

Problem 5. SPECIES IDENTIFICATION AND COUNTS BAND 3

Problem 4 was a sorting problem based on the types of shells in which hermit crabs live. This problem has to do with identifying the crabs themselves.

This difficult problem is obviously for upper elementary students. Identification may be done at the beach during an Extended Field Trip or in the classroom using hermit crabs which the students have collected from locations they have taken note of.

Materials.

-Hermit crab key (see descriptions and diagrams below)

Problems:

What different species of hermit crabs can you find in Hawaiian tide pools?

How many of each kind can you find?

Which kind or kinds are found most often? Least often?

Do all the hermits in one tide pool or along one shoreline tend to be all of the same species, or do they seem to mix together?

Hermit crabs are sensitive to pollution. What is the condition of the area in which your hermits were found?

Suggested Procedures.

If the students have completed problem 3 they are acquainted with the general anatomy of hermit crabs and know the names of the principal body parts. They could now be shown how to distinguish the different species by the size and coloration of the legs and claws.

Either the identification key, or the diagrams below, or both could be duplicated for student use or made into a wall chart for student reference. A valuable contribution to the class, useful for years to come, would be to let a few students reproduce the diagrams in large size for the bulletin board and color them, working from the live specimens as well as from the keys. Note that the key given here applies only to the five most common Hawaiian species. There are many species not shown here which the students might encounter from time to time.

The Waikiki Aquarium has a display of small tanks, each containing a different species of common hermit crab. Check with this display for further confirmation of types, leg colors, and scientific names.

Experienced BAND 3 students should be able to assume a large share in setting up needed data tables and organizing field trips for collecting information. Besides a data table for each student to carry, and on which to record observations, a large data table could be posted on the bulletin board on which to tabulate individual student data as they come in.

If the students have difficulty designing a good data table, the one below can be used as is, or modified to suit the class.

One or several Short Field Trips could be planned covering a different tide pool area each time, or an extended Field Trip could be arranged, moving from one shoreline area to another throughout the day.

TABLE __. SPECIES OF HERMIT CRABS COUNTED ON HAWAIIAN BEACHES

Grade ______ , School ______________________________

Date	Name of Place	Condition of Area*	Number of Each Species				
			Calcinus laevimanus	Calcinus elegans	Calcinus seurati	Calcinus latens	Clibanarius zebra

*sandy, rocky, clean, polluted, etc.

When all students know for sure how to identify each species, further hermit crab inventories by species could be done during weekend family outings or by students working shoreline areas of their own choice on their own time.

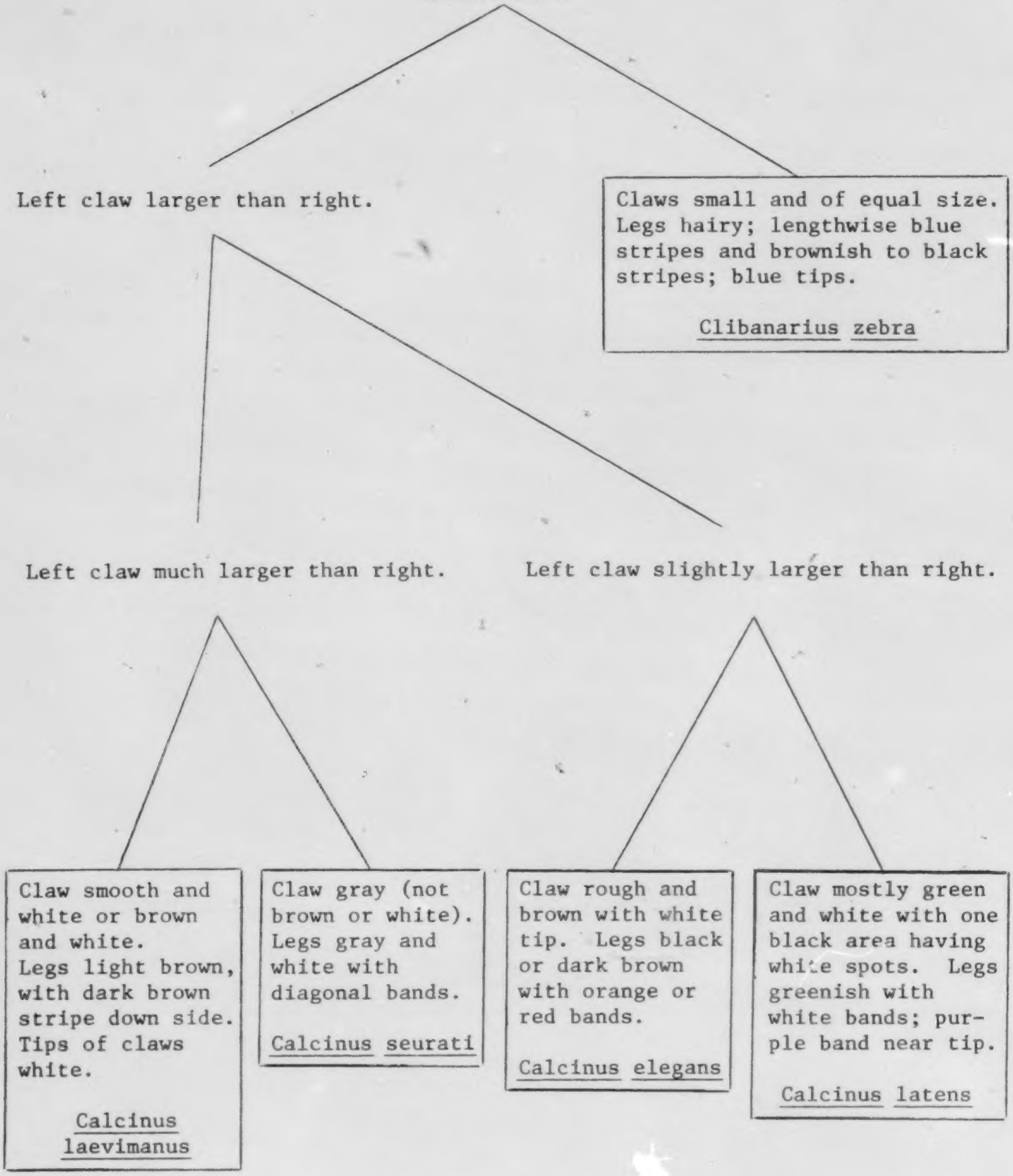
When the data are in, refer back to the problem questions and see if the data are providing any answers.

Let the data speak first. As a follow-up reference, note the diagram at the beginning of this topic indicating species preferences for different habitats.

Answers to Problem 5 can be developed into a formal scientific report in student notebooks using the format given in the PROGRAM MANUAL.

Hermit crab work offers a bonus to students in importance value. Dr. Ernst Reese at the University of Hawaii, Department of Zoology, has been engaged over many years with hermit crab statistics. Class data can be sent to the Hawaii Nature Study Project Office for forwarding to Dr. Reese. The data will be much appreciated, commented upon, and copies returned to the school. The students can thus be participants in a bona fide university research study.

FIVE COMMON HAWAIIAN HERMIT CRABS



Left claw larger than right.

Claws small and of equal size. Legs hairy; lengthwise blue stripes and brownish to black stripes; blue tips.

Clibanarius zebra

Left claw much larger than right.

Left claw slightly larger than right.

Claw smooth and white or brown and white. Legs light brown, with dark brown stripe down side. Tips of claws white.

Calcinus laevimanus

Claw gray (not brown or white). Legs gray and white with diagonal bands.

Calcinus seurati

Claw rough and brown with white tip. Legs black or dark brown with orange or red bands.

Calcinus elegans

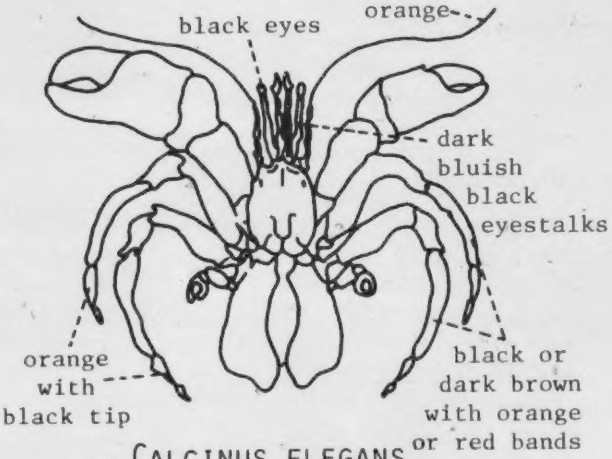
Claw mostly green and white with one black area having white spots. Legs greenish with white bands; purple band near tip.

Calcinus latens

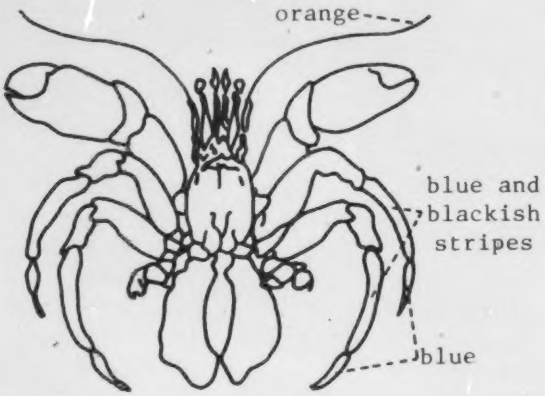
For identification of other common species, see the display at the Waikiki Aquarium.

DIAGRAMS SHOWING LEGS AND CEPHALOTHORAX OF FIVE COMMON HAWAIIAN SPECIES OF HERMIT CRABS (Dorsal or Top View)

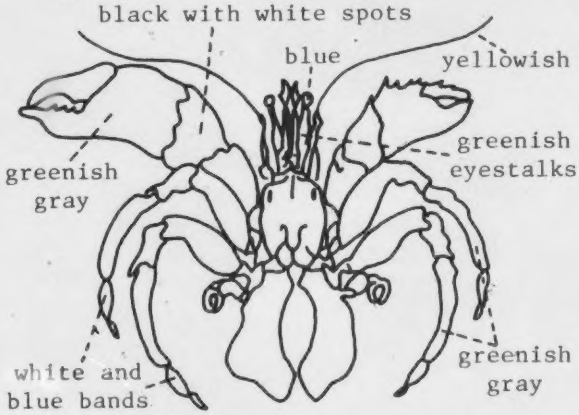
NOTE: Size of claws in the diagrams refer to adult specimens. Very young crabs show less size difference between the right and left claws.


black eyes
orange
dark bluish black eyestalks
orange with black tip
black or dark brown with orange or red bands

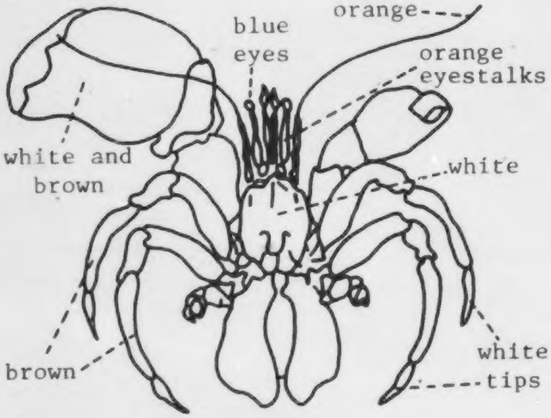
CALCINUS ELEGANS


orange
blue and blackish stripes
blue

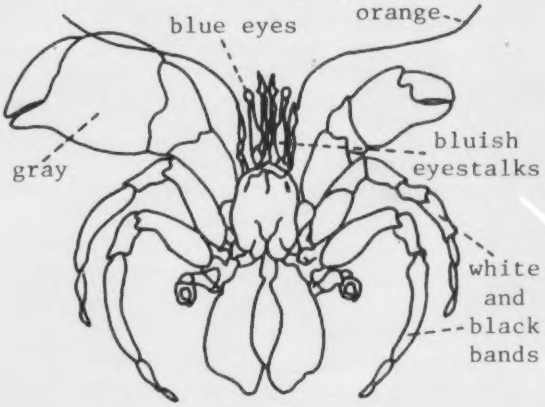
CLIBANARIUS ZEBRA


black with white spots
blue
yellowish
greenish gray
greenish eyestalks
white and blue bands
greenish gray

CALCINUS LATENS


blue eyes
orange
orange eyestalks
white and brown
white
brown
white tips

CALCINUS LAEVIMANUS


blue eyes
orange
gray
bluish eyestalks
white and black bands

CALCINUS SEURATI

2. TIDE POOLS

Introduction.

Tide pools are small, rock-rimmed basins carved by wave action into lava and coralline rocks along the shoreline. They are called tide pools or tidal pools because their replenishment with sea water is dependent upon the incoming tides. Some pools above the high tide mark receive water from the splash of the highest waves. Some are so low that they are exposed as pools only at the lowest tides. In Hawaii most of our tidal pools are actually reef flats with water trapped in pockets of the reef at low tide.

Tide pools make excellent marine study sites for elementary children because of their accessibility, their widely varying, measurable physical factors, and the variety and hardihood of their inhabitants.

Physical Features.

Tide pools range from inches to feet in diameter, from very shallow to knee deep. Tide pools may be as cool as the ocean water, or as hot as the rocks cooking in the sun after the waves have receded. Tide pool sea water may be diluted by the fresh water of light rains, or inundated by torrents of storm waters. A tide pool may be a maelstrom of swirling surf, then six and a half hours later become a quiet pool left isolated by the receding waters.

Tide Pool Life.

Tide pools are inhabited by a wide variety of very hardy little animals and plants having a wide tolerance to changing physical conditions. However even hardy and abundant tide pool life can be destroyed by over-collecting, by over-disturbance, by drying, and by crowding and insufficient aeration when collected and placed in class tanks.

Field Preparation.

Before considering this topic with a class, a teacher needs to determine where, within reasonable distance of the school, the best tide pools are located. It may be useful for the teacher to make a rough sketch of the area at low tide showing number and location of pools so that students can be assigned by groups to different observation sites.

Visits to tidal pool areas should always be made at low tide. Assistance in planning class visits is given in the Field Trip topic in Section 1 of this book. A Short Field Trip has the objective of spending a half hour or hour crouched around tide pools observing and taking notes which are discussed upon return to class. An Extended Field Trip is planned with tide pool observations, measurements, data taking, and discussion as part of an entire day in the field.

Observing in Tide Pools.

An important point to remember in tide pool observation is that impatient speedy lookers see nothing but empty water and a few sea weeds. The way to observe a tide pool is to "live" with it for a while. Sit next to it quietly and watch. Poke gently and slowly in the limu and in crevices. Look for small things. Use a hand lens.

Remember the rule: If you turn a rock over, turn it back. Do the students know why?

Besides the usual safety practices, students might be advised to do their observing with backs to the mountains and heads bent toward the sea. This position permits easier and safer reaction to an unexpected large wave rolling in with a returning tide.

Not everything can be seen in one session. Come back again and again to the same area. Visit the same and neighboring pools. There is enough life and ecology in tide pool work to keep a class profitably occupied for a semester, even a whole year.

Band Levels.

The questions and data sheets given in this topic are prepared with older elementary students in mind. This full presentation can be selected from and reduced to whatever level is appropriate for a given class. For primary children or any class beginning at a BAND 1 level, minimal portions of the suggested operations may be taken. For example, a young class might do only gross observations, omitting completely the measuring and data collecting. A half hour of just sitting and looking by small children might be followed by oral reporting of "what we saw in our pool", capped off with the telling of a sea story or of an ancient Hawaiian tale of the sea.

Tide Pool Investigations.

Problem 1. PRELIMINARY OBSERVATIONS OF TIDE POOLS BANDS 1, 2, 3

A general acquaintance with the features and the life in a tide pool makes a good introduction to tide pool work, both for the younger children who may not get much beyond simple observing, and for the older students who will later perform more sophisticated measurements.

Problems:

Is this tide pool high above the waves or down on the reef flat where water flows in and out of it?

Is this tide pool big or little, deep or shallow, warm or cool?

What different kinds of things are in this tide pool?

What are the different things in this tide pool doing?

Suggested Procedures.

Make a preliminary survey of the area before going out with the class. Chart the location of tide pools to be studied by student groups. Plan a field trip, either Short or Extended, for a period of low tide. Assign observation work to the students by groups, using the problem questions in the box, and/or other questions and points you wish to give.

How much detail and variety the students observe during the first and later repeated visits depends mostly on how long and carefully they look. Try to push them into looking long enough to get beyond the false premise that "This tide pool doesn't have anything in it."

BAND 1 children may make oral reports. BAND 2 and 3 students can begin their notebook recordings with this first problem, and later add further data.

Problem 2. PHYSICAL FEATURES OF TIDE POOLS BANDS 2, 3

Knowledge of the physical characteristics of a tide pool is essential to the understanding of the life which lives within its physical constraints, and limitations.

Materials.

- *Thermometers for taking temperatures*
- *Clip boards for holding data sheets*
- *(optional) Old knives or dull tools for poking into crevices*
- *Rulers or tape measure, preferably metric*

Problems:

What are some of the physical features of tide pools? Features to be measured include:

- Elevation and/or distance of pool from wave break line (measure by pacing off, by eye measurement, or by a rope or tape).

(Continued on next page)

Problems: (continued)

- -Shape and size of tide pool (e.g. round, oval, inches or feet across, deep hole, shallow, etc.)
- -Type of margin around pool (smooth, flat rock? rugged, jagged edges? steep sides?)
- -Depth of water in pool (Plan how to measure pools of uneven depth. Will you measure deepest part? average depth? other ideas?)
- -Type of bottom (sand? mud? rock? other?)
- -Temperatures. Use thermometers and compare temperatures of:

Water	Rocks Near Pool	Air
in bottom of pool	wet	just above water of pools
at surface of pool	dry	just above rocks
at wading depth in ocean	in sun	at waist height
	in shade	

When recording temperatures, also record time of day, cloudiness, or sun.

- -Salinity and other measurements can be taken by classes with facilities to take such data.

Suggested Procedures.

Discuss the problem with the class. Decide which measurements will be taken, by whom, and using which instruments. Divide into working groups:

> One system is to assign one group to each pool. Each group stays at its assigned pool and makes all measurements and observations for that pool. Pools are compared later so that everyone receives an overall view.
>
> Another system is to assign one group of students to do one set of jobs, e.g. one group does the thermometer work at all the pools, another does all the depth and size measurements, another sketches the animals in all the pools, etc. Information is shared later in class so that everyone receives a share of knowledge about each aspect.
>
> These two systems can be combined. A stationary group can be assigned to each pool to do all the observations except those requiring instruments. Special students can be assigned to move from pool to pool equipped with instruments (thermomemters, meter sticks, etc.)

The class should be clear as to which duties each group is responsible for during the trip. A preliminary duty is to prepare a blank data sheet, with as little help as possible from the teacher. Students who are not yet adept at designing data tables might be shown the following sample. This sample should be modified by the class or the teacher to reflect the class plan concerning which data is expected to be gathered.

TABLE 1. PHYSICAL FEATURES OF TIDE POOLS AT ________________

Items To Be Considered	Pool #1	Pool #2	Pool #3	Pool #4	etc.
Students reporting on this pool					
Shape of pool (sketch)					
Size (Set standards for measurements to be taken)					
Distance above low tide					
Distance below high tide mark					
Type and description of rocks surrounding pool					
Bottom features					
Salinity (if students have learned this yet)					
Special features					

TABLE 2. TEMPERATURES IN AND NEAR TIDE POOLS AT ________________

Items To Be Considered	Pool #1	Pool #2	Pool #3	etc.
Students doing measuring				
Time of day				
Sunny or cloudy				
Wind				
WATER TEMPERATURES: bottom of pool---------				
near surface of pool---				
in ocean (near shore)--				
ROCK TEMPERATURES: at rim of pool---------				
dry rocks in sun-------				
wet rocks in sun-------				
dry, shaded crevices---				
wet, shaded crevices---				
AIR TEMPERATURES: one cm above pool------				
one cm above dry rock--				
one cm above wet rock--				
waist high near pool---				
REMARKS				

The collected data can be discussed in conjunction with data collected for the next problem.

Problem 3. LIFE IN THE TIDE POOLS

BANDS 2, 3

Elementary children do not ordinarily know the names of algae, invertebrates, and fish found in tide pools. Neither do most of us teachers. This is only a minor handicap. Sketches and made-up names can serve for temporary recognition. Eyes, ears, noses, and fingers were made long before books which contain lists of scientific names.

Problems:

What different kinds of plants grow in this pool? color, height, "leaf" type, density, partly in or out of water, etc?

Do the plants grow all over the pool or in only some places? Which places?

What, if anything, does the sea weed contribute to the life of the pool? (hiding places for animals, food for grazers)

What fish live in this pool? size, color, shape?

How do the fish behave? Do they keep hidden in crevices, swim fast, swim slowly, jump from rock to rock?

What "sitting still" animals live in this pool? What are their kinds, shapes, numbers?

What lives in the bottom of the pool? If there is a muddy bottom, what lives in the mud? Can you see tracks or holes in the mud or sand in the bottom?

What lives hidden in the crevices of the rock and among the holdfasts of the sea weed?

Question for follow-up discussion:

Compare the pools observed by different groups of students.

Suggested Procedures.

Plan the field trip work with the students, selecting questions from the above list or inventing others to be pursued in group assignments at designated pools.

Data sheets need to be prepared ahead of time. If students have difficulty devising a blank data sheet, the following table can be modified to fit the plan of action. A separate table is needed for each student group or for each tide pool.

TABLE 3. PLANTS AND ANIMALS IN TIDE POOL NUMBER ______________

This tide pool is (high
(middle
(close to ocean)

Observers at this pool are ______________________________

Items To Be Considered	Plant or Animal #1	Plant or Animal #2	Plant or Animal #3	etc.
Sketch of plant or animal seen in pool.				
Name if known. Otherwise a made-up phrase which describes it.				
Location of plant or animal in tide pool.				
About how many of this plant or animal are seen in this pool?				
Behavior of animal (What is it doing?)				
Other observations.				

Follow-up Discussion for Problems 2 and 3.

Discussion of data on both the physical environment (Problem 2) and of the biota (Problem 3), can be done either while gathered in a group at the beach during an Extended Field Trip, or after returning to class. The following questions may be useful insofar as they apply.

Problem 1. Physical Features

-What features did all the tide pools have in common?

-What were some of the biggest differences or variations among the tide pools?

-Do you think a tide pool is like a rain puddle in the school yard? How or how not?

-Compare the temperatures of water, rocks, and air.

-What might cause the higher or lower temperatures at different places?

-How might the temperature change at different times of day? Would you predict that the rocks, air, and water will cool or heat the same amount or at the same rate during different hours of the day or night? How could you find out?

Problem 2. Life

-Did your pool contain more plants or more animals?

-How do the tide pool plants differ from land plants? (Many limu are not green; their "leaves" are different.)

-Can you think of any uses or values for the tide pool plants? (food for people, food and hiding places for tide pool animals.)

-What animals did you find in your pool? (You might explain here that anemones are animals.)

-Were there many animals of any one kind? Which kinds were most abundant?

-Did any of the animals come out of the tide pool? (The little Blennies and Rock Skippers often jump out.)

-Do you think you missed seeing any of the animals? (The students probably missed about 90% of them due to inexperience in observation, the camouflage of the animals, and their ability to hide in crevices.)

Discussion of Ecological Data: Comparisons.

Look for sets of data which seem to correlate. Correlations and comparisons become evident when data from individual groups are amalgamated into one big chart. The following suggestions may assist in buiding the comparisons.

-Compare the plants, animals, and physical characteristics of the different pools. In what ways were all the pools alike? In what ways did they differ? Can you account for the likenesses and differences?

-Compare number of fish with size of pool, depth, distance from low tide, temperatures.

-Compare types and numbers of invertebrates with presence or absence of sea weed, type of bottom, size and depth of pool, distance from low tide mark.

-Examine data for things which seem consistently to be found together such as sea urchins and sea urchin holes, sea cucumbers and sandy bottom, and other related sets of data.

-Examine data for animals which seem to live close together or in bunches (e.g. brittle stars) in contrast with animals which seem to occur only one or two, here and there.

-Note any data which seem to increase or decrease together, e.g. the higher above the tide line, the more periwinkles, if this is the case.

-Ask the students how many animals they saw in their first one minute of watching, and how many they saw after quiet watching for a long time.

-Ask: If you were a tide pool animal, which animal would you prefer to be? Why?

-Ask: If you were your favorite tide pool animal, which of the tide pools examined by the class would you choose to live in? Why?

Conclusion and Reports.

Discussion is followed, or accompanied, by written (and possibly illustrated) notebook reports. See the PROGRAM MANUAL for reporting styles. Less experienced students even if they are in upper classes, will write less complete reports until they have had opportunity to practice report writing.

Specific tide pool animals which catch student interest create a point of departure for making a special study of those individual animals. Many common tide pool animals are treated as separate topics in this book with problems and background for their special study.

3. TIDE POOL IN THE CLASSROOM

Introduction.

Bringing a bit of tide pool back to the classroom allows for more detailed observation and prolonged data taking of certain aspects of what was observed in the field. A classroom "tide pool" is not a substitute for field work. It is a follow-up study.

Materials.

-Flat, non-metal pans (plastic shoe boxes, glass baking pans, flat, plastic pans)
-Supply of sea water
-Tide pool material collected during a preliminary field trip
-Hand lenses for observations

Problem: BANDS 2, 3

Do a detailed study of one aspect of a tide pool. (see below for examples)

Suggested Procedures.

1. Set up flat pan aquaria, possibly one pan per student group. See Section 1 of this book on flat pan aquaria. Note what is said there about evaporation from flat pans, salinity levels, tilting of pans, and aeration from open surfaces.

2. From observations made and knowledge gained during field trips, select a classroom tide pool study. The students should have some ideas and preferences from their field experience.

3. Collect living materials from pools as needed, keeping conservation practices in mind. The collection can be made by students before school or during a special Short Field Trip to the beach by the class to gather materials for the classroom set-up. The students who maintain the classroom study should do the field collecting so that they can compare their classroom conditions with the actual habitat. Use a battery operated pump during transport of the animals from ocean to classroom.

4. A data sheet should be designed and placed next to each classroom tide pool and information logged in it at each period of observation, i.e. daily or several times per week.

5. The following types of classroom tide pools or others of your own design might be set up, depending upon preference and availability of materials.

a. A Miniature Tide Pool.

Gather from a real tide pool a little bit of each kind of thing found there, such as a small clump of sea weed, a small scoop of bottom material, a few hermit crabs, shells, etc.

Observe how these find hiding places and select food from day to day, how they survive, and how they establish "in-house" relationships.

b. A Mud Bottom Tide Pool.

Collect a few scoops of mud bottom and put it in a classroom pan covered by very shallow sea water.

Each morning, look for tracks and holes in the mud as well as actual animals. Keep data on kinds and populations, their survival, other changes.

c. A Sea Weed Tide Pool.

Gather a clump of sea weed from a reef flat, transferring it quickly from its natural habitat into a bucket before small animals have a chance to escape. Place the clump with its inhabitants in a classroom pan barely covered with sea water.

Take daily data on kinds, numbers, and behavior of whatever lives in and around the clump.

d. A Variegated Classroom Tide Pool.

Set up a very large but shallow classroom tide pool covering the top of an entire table. (Use a plastic shower curtain to line a large flat cardboard box to get a large flat pool.) In it put a variety of habitats, such as clumps of sea weed in one corner, rocks placed here and there, sandy bottom in one place, mud in another, and so on. Besides keeping the water shallow, a few air stones can be added, artfully hidden under stones.

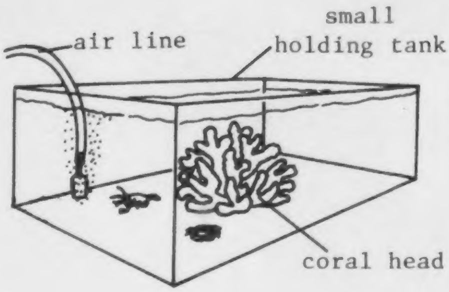
Have the students, with help of a hand lens, make sketches of all the tiny animals they can find in the pool. Since new animals keep crawling out of the rocks and sea weed, this may take days or even weeks. One pilot teacher had her fourth graders take their sketches home to ask parental help with identification. This generated considerable interest both during and after school.

e. A One-Rock Tide Pool.

Set up a glass gallon jar or a small aquarium with a bare bottom, clear sea water, and an airline, possibly one or two airstones anchored near the rock after it is installed.

Pick up a small coral head or other rock from underwater on the reef flat and place it immediately in a bucket of sea water before any animals have an opportunity to run out. Transport to the classroom using a battery-operated pump.

Establish the rock in the classroom container and watch daily for what comes out. Keep data. Make sketches. Feed and aerate as dictated by the nature of the beasts which emerge. Transfer animals as desired, one by one to the regular classrom aquarium.



6. Further Ideas for Classroom Tide Pool Studies.

Each student group may set up a small classroom tide pool of the same type but each located in a different part of the room in different degrees of light. Compare effects of differences in light on survival and behavior.

Each student group may set up a classroom tide pool under the same conditions of light, temperature, etc. but each containing different populations of animals. Note which animals thrive and which do not under similar conditions.

Each student group may set up classroom tide pools having the same populations but at different depths of water, sizes of pans, and other physical differences. Check effect of greater or less space on behavior and survival of populations.

Conclusion.

At the end of the classroom tide pool study, surviving animals should be returned to the sea.

Student reports should be made in notebooks showing statement of problem, conditions of and methods of study, data, sketches, and conclusions.

Later topics in this book give problems and suggestions for investigating some specific tide pool animals such as hermit crabs, periwinkles, and many others.

4. CRABS AND SHRIMP *

Introduction.

Crabs are one of the more active intertidal animals. What would the seashore be without crabs scurrying over rocks, streaking across sandy beaches, or sculling near river mouths? Crabs along the shoreline are varied, abundant, and active, qualities which make them appealing to youngsters.

Not all of the field and classroom problems in this topic can, or even should be pursued in one year. The simpler ones (BAND 1) can be done by younger children or by older ones during their first year of exposure to Reef and Shore activities. The more complex problems, especially those marked for BAND 3, are suitable to upper elementary classes after the students have had one or more years of previous experience with Reef and Shore investigations.

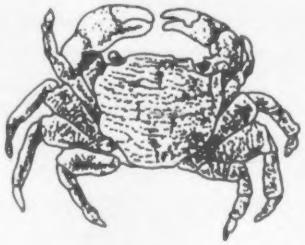
Teacher Background Information.

Crabs, shrimp, and their kin have a crusty, segmented skin and jointed legs. They populate the ocean with a diversity of colors, sizes, and functions.

Despite some exceptions, true crabs are short, wide, and flattened top to bottom. Shrimp are long, narrow, and flattened side to side. This basic difference in body plan is due in large part to the presence or reduction of a tail, or more properly, an abdomen. Crabs are "short-tailed" and what abdomen they do have usually is flexed under their head-chest. They also have short, stubby antennae, as opposed to the long, graceful antennae of shrimp. Generally, crabs walk (usually sideways), while shrimp swim.

Although the students may find a crab from any of the families of crabs, some crabs are more likely to be found than others. These are the rock, swimming, ghost, and mole crabs.

Rock Crabs. Family: Grapsidae (grăp' sĭ dē). Squarish "backs"; eyes on short stalks near two front "corners", large space between eyestalks; pointed legs; flattened body and legs; dark color. Found on rocks, high tide zone.



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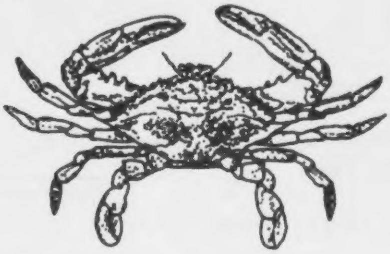
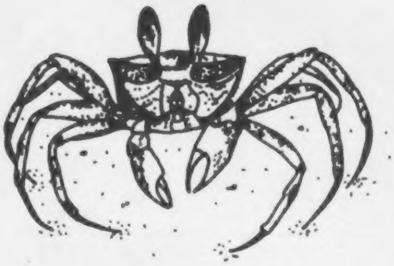
*"Crabs and Shrimp " was developed, written and field tested by Barbara S. Culliney.

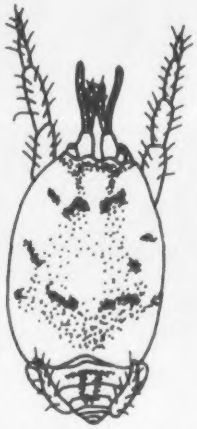
Swimming Crabs. Family: Portunidae (pŏr to͞o' nĭ dē). Fifth pair of legs has last segment flattened to serve as a swimming paddle; widened "back", often terminating laterally in a point. Several species often found swimming near the mouths of streams; other species may blend in and be partially buried in sand or mud.



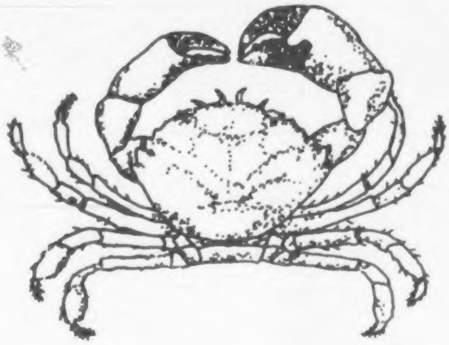
Ghost or Sand Crabs. Family: Ocypodidae (ō sĭ pō' dĭ dē). Pale color; eyes on long stalks, with small space between them. Found on sandy beaches above waves; in deep burrows or running fast over beach.

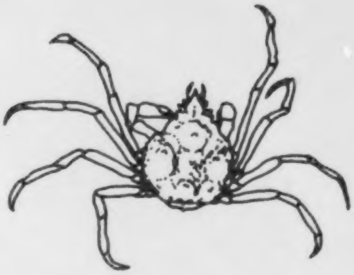


Mole Crabs or Sand "Turtles". Superfamily: Hippidea (hĭ pĭ dē' ă). Not a "True Crab"; body rounded, rather than flattened top to bottom; long, feathery antennae. Found in surf zone of sandy beaches; may be seen in times migrating en masse to stay in surf as tide ebbs and floods. The Hawaiian mole crab diagrammed here is *Hippa pacifica*.

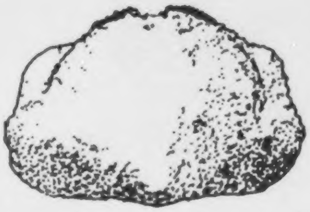


Black-fingered Crabs. Family: Xanthidae (zăn' thĭ dē). "Finger" of claw usually colored black or dusky; roundish "backs" (so some types called "pebble crabs"); pointed legs; chunky, hefty body. Various habitats: many kinds found in and among branching corals; other kinds along rocky shores at low tide; often found in same area as rock crabs, but Xanthids usually found *under* rocks.





Spider Crabs. Superfamily: Oxyrhyncha (ŏx' ē rĭn' kă). Triangular "back", long legs and small body gives a spider-like appearance; curled or hooked hairs on back used to hold on to sea weed, etc. to disguise itself, so often called "decorator", "masking", "sea weed", or "camouflage" crabs. Found in limu on reef; may be washed ashore in the midst of the limu.



Box Crabs. Family: Calappidae (kă lăp' ĭ dē). Crabs "close up" like a box when disturbed; outer edge of "back" has a narrow "shelf" that hides legs when they are held tightly underneath; claws are modified to fit snuggly against the crab's face. Found in sandy areas, in water.

GHOST OR SAND CRABS (OCYPODIDAE)

Introduction.

Who makes those holes and tunnels on sandy beaches? Two species of shy crabs known as sand or ghost crabs, that's who. They are called ghost crabs because they are more commonly out at night, and because one species in particular is pale and very difficult to see against the sand.

Because of their ubiquitous presence on all Hawaiian beaches, sand or ghost crabs make a good point of introduction into the crab world.

Problem 1. MYSTERY BEACH HOLES BANDS 1, 2, 3

This is a topic to pursue during a field trip to the beach. It can begin with an examination of those multitudinous holes in the sand of all types, sizes, and origins.

The problem questions given below, seemingly addressed to students, actually need to be adapted by the teacher to fit the situation at hand. Some questions may be asked at the beginning of the field lesson. Then give time to make observations and draw inferences which can lead into further questions. Not all the questions listed here need be used. On the other hand, students may ask useful questions not anticipated here.

Problems:

Notice the holes in the sand of the beach. How do you suppose these mysterious holes were made? Do you think some person poked a stick in the sand? Could the waves have made them? Do you think maybe an animal dug them? Are there any tracks or other clues around the holes to help you formulate an hypothesis? Keep your hypothesis in mind as you consider the following questions.

Are most of the holes close to the sea water, or far up in the upper beach zone? How can you accurately find out?

Which direction do the holes face? Can you think of a reason for this?

How wide are these holes? Are the big ones or the small ones closest to the waves?

Are there piles of sand near the holes? If these mounds haven't been disturbed, can you determine if they have different shapes? Do large holes have differently shaped mounds than sand piled near small holes?

Look inside the holes. What does the tunnel look like? Does it seem to go straight down sharply? Or does it seem to curve to one side and go down gradually? Do small holes seem to have one kind of tunnel and large holes another? Try digging up different kinds of tunnels with your hands; go slowly and carefully, to see what kind of paths they make as they go down.

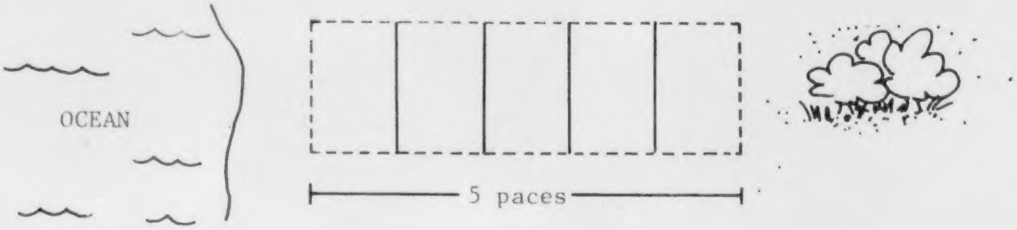
Sit down about 10 yards (or meters) away from the waves' edge. Be very quiet and motionless, and watch the holes. If you are quiet, something will come out of the holes! What is it? What do they do? Wave your arms; now what do they do?

How can you get one of these animals for a closer look at it? Can you dig it up? Can you catch it? Can you trap it?

Suggested Procedures.

1. Perhaps the holes will obviously be more numerous in one part of the beach than another. On the other hand, perhaps they will seem to be evenly distributed. In order to get an accurate picture of where the holes are (and consequently, where ghost crabs live), students may suggest counting the holes. Help them decide on a standard area in which to count all holes.

   For example, you may want to pace off an area running along the beach (say, four "teacher's paces" wide) and extending all the way inland to the trees and shrubs, or to where the last hole is (say, 25 "teacher's paces" deep). Divide the strip by pacing off the length into five "teacher's paces" subsections, like so:



You may want to designate several such areas on the beach, and divide the class into groups, each one responsible for counting holes and reporting results. The students can then average their findings and perhaps draw up a graph when they return to class. What conclusions can be drawn as to where ghost crabs like to live best? (This question is more complex than is indicated here because there are two species of ghost crab, living in different parts of the beach. Perhaps students will discover this from their sampling; perhaps they will get a "bimodal distribution", one with two areas of high numbers of holes, one in the upper beach, the other in the lower beach.) For upper level students, data on sand crab populations can be developed into a formal scientific report.

Teacher Background Information.

Sand crabs spend most of their time on land, returning to the sea occasionally to rewet their gills, and for reproductive purposes.

Once it is made, a ghost crab tends to keep to his own burrow, returning to it from five to ten yards away when alarmed. He may guard his burrow against crab intruders.

Burrows are sometimes deeper than four feet, being dug as deep as necessary to reach moist sand. If a ghost crab starts the entrance of his tunnel at a very high tide location, he has a long way to dig!

A mature male ghost crab's tunnel can be distinguished from those of females and juveniles. First of all, the pile of sand outside of a male's tunnel is large and comes to a peak. (looking down along the shore, they resemble an encampment of tepees!) Perhaps these high, peaked sand piles help attract females to the males' burrows during mating season. The opening to the mature male's tunnel is quite large, and, looking inside, the tunnel veers to one side as it descends. If you trace it further, it continues to curve corkscrew-fashion, terminating in moist sand. On the other hand, a juvenile or female tunnel is marked by a rounded mound of sand; its opening is small, and it drops rather steeply straight down.

Since the crabs burrow with their largest claw directed toward the burrow entrance, you can determine whether a crab is right- or left-handed by looking at the direction of spiraling of the burrow. If a burrow spirals down toward the left, the large claw is on the left side of the crab that dug the burrow.

There are two species of ghost crabs in Hawaii. One (Ocypode laevis) is small, has yellow eyes with brown on top, and generally lives closer to the grasses and bushes. The other species (Ocypode ceratophthalmus) is larger, has purplish-brown eyes and body, and tends to live closer to the shore. The larger species is easier to catch, because it wanders farther from its burrow, but is harder to keep alive because it is more apt to fight and damage itself.

Problem 2. CATCHING GHOST CRABS BANDS 1, 2, 3

The point of this activity (besides being lots of fun) is to obtain a number of specimens for closer observation.

Materials.

(optional, depending on method used)

-One or more shovels
-One or more box sieves (see diagram below)
-Several one-inch mesh (red-mesh type) nets
-Several buckets or large, deep cans (e.g., three-lb coffee cans)

Problem:

Catch some ghost or sand crabs.

Suggested Procedures.

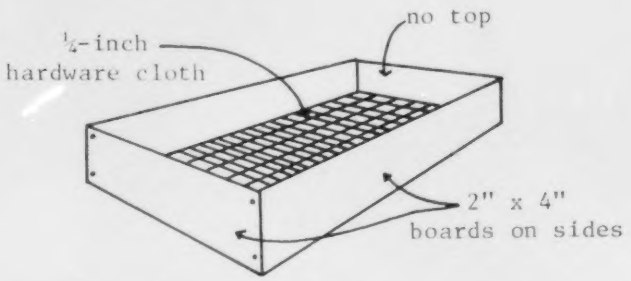
Catching sand crabs takes some doing, even given the advantages of nimble feet and hands. The students may have ideas on how to get a ghost crab from their own beach experiences. If they need some ideas, you might want to suggest one of these:

1. Catching Crabs by Hand or Net. It is easier to collect ghost crabs at night, but you can at least try catching them during a daytime field trip. They may be difficult to catch because they are such fast runners (as much as 1.6 meters per second, or 10 mph!). Try waiting motionless until a crab has wandered away from its hole. Try and catch it with a net. Maybe a partner can block the crab's path to its hole. Be quick!

2. Digging Crabs. Some ghost crab burrows are quite shallow; children building sand castles sometimes uncover them.

   A crab at the bottom of its burrow may be digging its hole deeper as fast as you can dig with your hands. So, you may want to dig quickly using a shovel. If the crabs still get away, you may want to try this method. One student digs with a shovel, piling the sand in a box sieve held by one or two other students. These students should shake the sand through the sieve. Perhaps several other students could help the sieving process by pouring sea water from buckets gently through the sieve. Despite your best efforts, sometimes a crab may escape out another entrance!

BOX SIEVE



3. Trapping Crabs. Baited traps that require someone to be present do not seem to work, or at least they may take so long to work as to be impractical. But perhaps students can locate an area where there seems to be a lot of ghost crabs (i.e., a lot of holes), dig a hole, bury a bucket or large can up to its brim, bait it (perhaps with a freshly opened clam or mussel), and leave it alone for a half-hour or so. Presumably, any ghost crabs that get into the bucket will not be able to get out.

Problem 3. OBSERVING SAND CRABS IN THE CLASSROOM BANDS 1, 2, 3

This problem entails bringing some crabs, preferably a few small ones caught at the beach, back to the classroom for closer observation of their anatomy and behavior. Ghost crabs, particularly the larger of the two species, tend to mutilate each other when confined together in a small space. Therefore, it would probably be best to carry only one per bucket back to the classroom. Take some sand, and sea water in its own container.

The first job in the classroom is to maintain the crabs adequately. A decision by the students on how to house and care for the crabs can constitute the first part of the lesson.

Materials.

-A few small ghost crabs
-A big, deep container (e.g., plastic dish pan, aluminum roasting pan, etc.)
-Sand
-Sea water
-Saucer, or plastic jar top, for water and food

Problems:

Housing:

Where was the ghost crab found? In the water or in the sand?

Would it be better to put the ghost crab in a mostly watery place, like an aquarium, or in mostly a sandy place?

Food:

What different things would you try to feed the ghost crab? What does it like best? How does the ghost crab eat?

Air:

How do you suppose a ghost crab breathes? Do you think it needs water to breathe? See what happens if you put a little saucer, or plastic jar top, filled with sea water in the sand. Does the crab use this water?

Crab Communication:

See if you can find a ridge of little bumps on the inside of one of the claws. Closer to the body on the same claw, can you find a knob? What would happen if the crab rubbed the ridge over the knob? What happens when you rub a hair comb over a knob, or something else hard, like the edge of a table? What could this ridge-and-knob system be used for? If you find a dead ghost crab, or an old skin (molt), rub the ridge on the claw against the knob. What sort of sound does it make? If you have a magnifying glass, what does the ridge look like? Are there many parts to it? Could the crab make more than one kind of sound? Do both male and female ghost crabs have this ridge-and-knob system? Why might crabs make sounds? (warning of territorial limits, mating call)

Crab Behavior:

How do ghost crabs behave toward one another? Are they friendly? aggressive? unaware of one another? Do ghost crabs spend most of their time sleeping or resting, or do they run around a lot? How do they move? quickly? slowly? with jerks, stops, and starts? smoothly? What else do ghost crabs do?

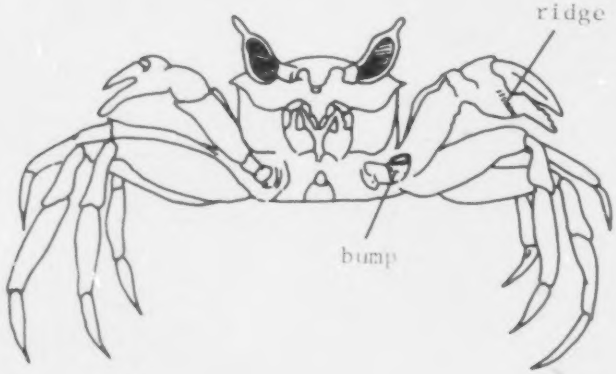
Suggested Procedures.

Start with a fairly big, deep container (e.g., new/clean plastic dish pan, or transparent plastic box) with a layer of wet sand in the bottom. Place a shallow container of sea water flush with the sand so that the crab can rewet its gills from time to time. This water will need to be emptied and refilled usually every day (maybe it can go Friday to Monday without a change) to keep the right degree of cleanliness and salinity. Put a top across the container, to keep the crab's environment humid, but leave it slightly ajar to allow for some aeration.

Ghost crabs have wide food preferences, being both scavengers and hunters in their natural habitat. You might try feeding them pieces of fish, mussel, or hamburger. Try the pill bugs and insects that students can gather underneath rocks in the school yard.

Other classroom activities with sand crabs entail observing the parts of their bodies and distinguishing males from females. Body parts of crabs are described under "Rock Crabs" and "Swimming Crabs" but can be used here with sand crabs also.

Student notebook reports on sand crab observations could include a number of student diagrams as well as recordings of observed behavior.



A ghost crab can make a "filing, creaking, or buzzing" sound when it rubs a ridge on the inside of one claw against a bump on the same claw.

Problem 4. BABY GHOST CRABS BANDS 2, 3

This investigation is best done at the beach, probably by the older students.

Materials.

-Bowl of sea water

Problems: BANDS (1), 2, 3

Find a tiny ghost crab hole as close to the edge of the waves as you can. What clues will you look for to help you decide which is a ghost crab hole and which is a small air hole?

(cont'd on next page)

Problems: (cont'd)

Dig it up carefully. Look for something that looks like a small (3/8-inch diameter or smaller) pebble. It may be bluish.

If you find this "pebble", put it in a bowl of sea water. What happens? Look carefully; what do you think this "pebble" really is?

Suggested Procedures.

Help the students look for holes with tiny balls of sand near them, and other signs of crab activity.

Of the two species of ghost crab, the larger has a late-stage larva that is bluish.

See Teacher Background on Crab and Shrimp Young for more information.

Student notebooks might reflect student observations, opinions, or whatever data was collected about juvenile sand crabs.

ROCK CRABS (GRAPSIDAE)

Introduction.

Grapsid crabs are usually found scurrying over rocks in the upper tidal zone. They are covered by the tide only occasionally. When chased, they hide under rocks. Their flattened bodies and legs help them crouch against the rocks to withstand the force of splashing waves. This body shape also seems helpful when they edge under very narrow spaces between rocks, or between rocks and gravel.

Rock crabs are a convenient group by which to get into a study of crab behavior and anatomy. Rock crabs are relatively easy to catch; they are plentiful so there are enough to distribute among the students, and their claws are not as awesome as other kinds!

Problem 5. CRABS ON THE ROCKS (Field Work) BANDS 1, 2, 3

The questions in this problem are intended to draw attention to rock crab habitats, behavior, and camouflage in their natural environment. The questions given here can be discussed with or given to the students before going on a field trip, or the teacher can sit on the rocks with the students and generate questions similar to these as events dictate.

Problems:

Examine the black lava rocks along a shoreline area to look for crabs. Sit quietly on the rocks just above reach of the waves and watch for them. Where do the crabs hide? How long does it take them to venture out after your arrival frightened them away?

Do many crabs seem to occupy the same hole or crevice or do they each live alone?

When they do come out of hiding, where do they go? What do they do? How do they move?

What colors are the rock crabs? Of what benefit to the crabs might their color be?

How far above or below the water and the tide line do they seem to live?

Suggested Procedures.

If students are to be successful in doing field observations of rock crabs they will have to be convinced to sit very quietly for a relatively long period and watch. Depending on the class and the location of the school, this could possibly become a homework assignment for over a weekend.

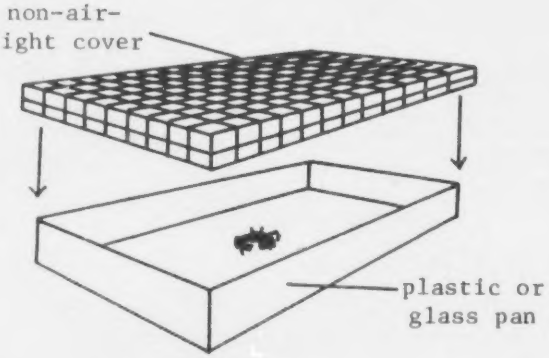
Observations can be given emphasis by having the students report orally, by having them make a bulletin board display or mural of rock crab habitats with crabs visible, or by individual notebook reports.

A sequel to this problem is to catch a number of rock crabs for closer observation in the classroom. With patience and a little speed, this can be done by hand. Since the rock crab pincers are relatively harmless, the crabs can be grabbed without fear and quickly popped into a mesh bag or covered bucket.

To transport rock crabs back to the classroom, put enough water in a bucket to come mid-way up the crab; they do not need to be immersed in water. It would be a good idea to bring some extra sea water in another bucket; this can be used to set up crab trays in the classroom.

Grapsid crabs normally pick algae off the rocks they live among. Gather some of these rocks and transport them back to the classroom in a moist bag separately from the crabs. In this way, the rocks will not roll over the crabs, possibly damaging them, during the ride back to school.

Laboratory Maintenance.



Although rock crabs can be kept in the regular classroom aquarium, in their natural habitat they are not normally under water for long periods. Therefore, it would be better to set them up in pans similar to those described for hermit crabs. Pans also allow for better observation of the crabs' individual and social behaviors.

Put the whole pan in a stocking, or cover it in some other non-air-tight way, otherwise, the crabs may escape and die in some corner of the classroom.

Some specimens can be kept in small, plastic glasses or glass jars. Crabs in glasses can be passed easily from student to student for observations. Plastic bags filled with sea water might make good viewing containers although the crabs' pointed legs may possibly puncture the plastic.

Grapsid crabs are usually omnivorous. Besides eating the algal film on rocks, they may catch small or hurt animals, even their own kind, particularly if they are crowded together. In our experience they did not seem to like raw fish.

Problem 6. CRAB SPEED BANDS 1, 2, 3

Crab races can be held with primary students as a fun game, and with older students in combination with a mathematics lesson. Both rock crabs and sand or ghost crabs make good "contestants" for this activity. Swimming crabs can also be used.

Materials.

-Rock or sand crabs
-Stopwatch, or watch with a second hand (BAND 3 only)
-Yard or meter stick (BAND 3)
-String (BAND 3)

Problems:

Can you think of a way to measure how fast a crab moves?

How fast do crabs run? How fast do they run compared to us?

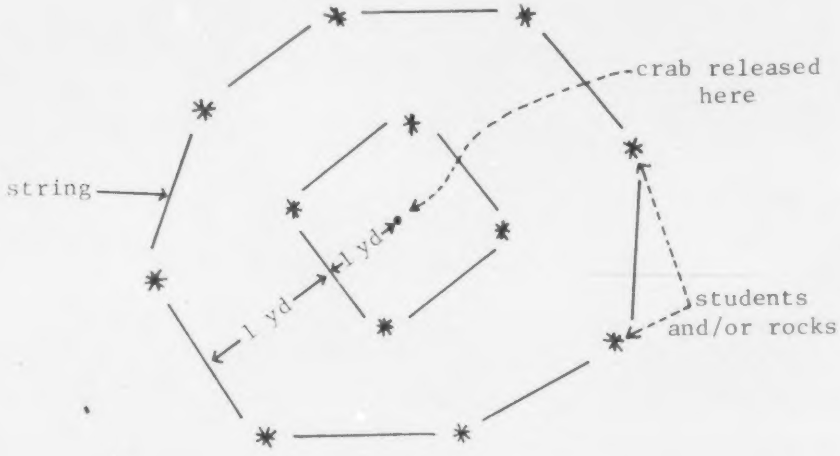
Where or toward what do crabs run?

How do they behave when they arrive at the waters' edge?

Suggested Procedures.

Students may have ideas on how to measure a crab's rate of movement in getting away. Help them realize they will need to establish starting and ending points.

A "race course" might be constructed by laying out concentric circles of string on a smooth area of beach with children stationed at intervals to observe and time the "contestants". Rocks might be used as obstacles, as crab "goals", as attraction centers, for crabs seeking shelter, or as anchors for the string.



The starting point is where the crab is let go. The end point can be the edge of the water or any landmark on the beach such as a rock or the place at which the crab crosses the string. Measure the distance between the starting and end points. This distance, divided by the time it takes the crab to travel it, is the rate.

If more than one crab is raced, you could measure the rate of each and get an average. Are males or females faster?! Maybe you would also want to measure each crab across the back to see if smaller or bigger ones move faster.

One author calculates sand crab speed to be about 1.6 meters per second. How do his results compare with yours? How does this compare with rock crabs?

To compare a crab's speed to the students', mark out a race course and time several students' running speed. Calculate in meters or feet per second to compare with crab speed calculated in the same units.

If a human person and a crab run at similar speeds, is it "harder" for the human being to do this, or for the crab? What do you need to consider to answer this question? Which animal is heavier? Which animal needs to take more steps to cover the same distance? This is a difficult question to answer, even for research scientists, but thinking and wondering about it helps us appreciate crabs and other animals.

Problem 7. APPEARANCE AND PARTS OF A CRAB BANDS 1, 2, 3

Observations on Grapsid crabs captured from rocky shorelines as indicated for this problem apply to crabs generally. Rock crabs are suggested for appearance and behavior studies because of their abundance, more or less typical crab features, and their relatively weak pincers.

Materials.

-Pans or containers, holding rock crabs and covered with mesh
-Magnifying glass(es) (optional)

Problems:

What color is this crab? How might this be a good color for the crab? (Hint: What color is the sand or rocks where you found this crab?)

How does a crab feel to you? What sort of skin does it have?

Compare the crab's body plan to yours:

You have a head, chest, and abdomen. Does a crab have a similar body plan?

You have two arms and two legs, or four "appendages". How many appendages does a crab have?

How many sections, separated by joints, are in your leg? How many in a crab's leg?

Your hands are different from your feet. Can you see differences in the crab's appendages?

What does a crab's mouth look like? Does it have lips? Can you see any teeth?

Does a crab have eyes? eyelids? Can the eyes be moved?

What are some things that a crab has that you don't have?

How do the various kinds of crabs you have observed resemble one another? How do crabs resemble shrimp? How are they different from shrimp?

How many females do you have? How many males? (see Problem 8)

(cont'd on next page)

Problems: (cont'd)

Can you distinguish the crabs as individuals?

Can you see water moving near a crab? What is making the water move? Blow air in and out of your mouth. If this air were water, would you be making a water current?

Can you see in what direction the water current is going? Do you think the crab is benefitting from this water current? If so, how?

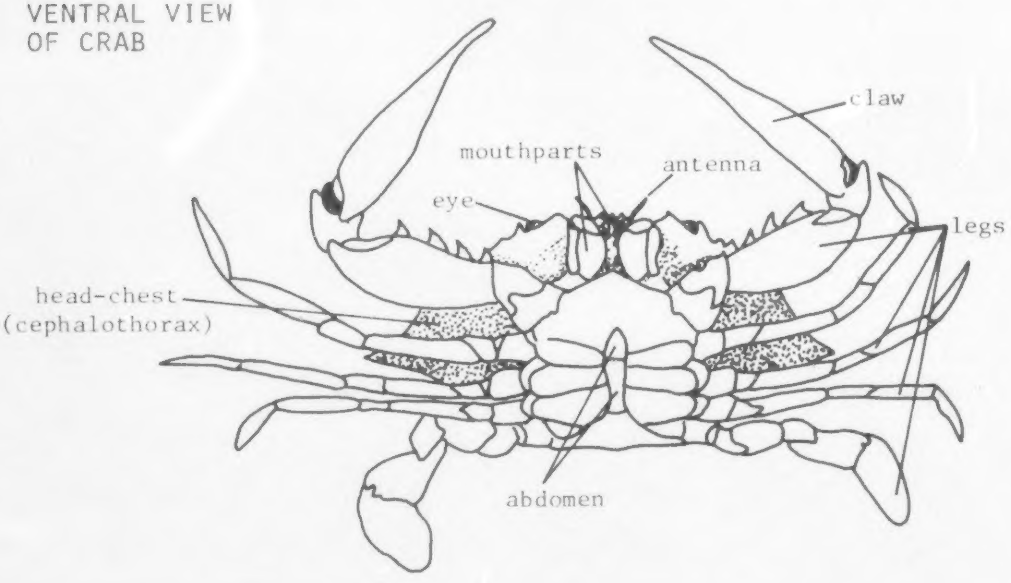
Suggested Procedures.

To make it easier for all children to participate in crab studies, it would be a good idea to have several trays around the classroom, with a few crabs (maybe up to a half-dozen crabs, depending on the tray size) in each tray.

If the students have seen other crabs for comparison, help them to notice the Grapsid's flattened body and appendages.

Even though it appears to be almost still, if you carefully watch a crab in water, you may see it creating water currents. The pattern may vary with crab type, but water is generally drawn in over the gills at the base of the two claws and forced out through the mouthparts. In this way, the gills can extract oxygen, and the mouthparts can filter food particles. Perhaps the water currents can be seen more readily if the surface of water is sprinkled with a tiny pinch of chalk dust.

VENTRAL VIEW
OF CRAB



Teacher Background Information.

All crabs belong to the group called "Decapoda", meaning "ten legged", a term that is easily demonstrated with most crabs. If the class is looking at mole crabs, which are not true crabs, it may be hard to find the fifth pair of legs since they are reduced and hidden by the fourth pair.

For a few specifics on whichever type of crab you are observing, see the diagrams and brief descriptions of crab families at the beginning of this topic.

Problem 8. CRAB SEXES

BANDS 2, 3

Sex distinction given here for rock crabs, applies to crabs in general.

Materials.

- *Male and female crabs distributed to groups of students*
- *Covered containers in which to keep the crabs when not being observed*
- *Magnifying glasses (optional)*

Problems:

Look at the claws of all the crabs (of the same species, or kind) collected by the class. Do some crabs have bigger claws than other crabs? Which do you think would have the bigger claws, males or females? Why? What do you think these big claws are used for?

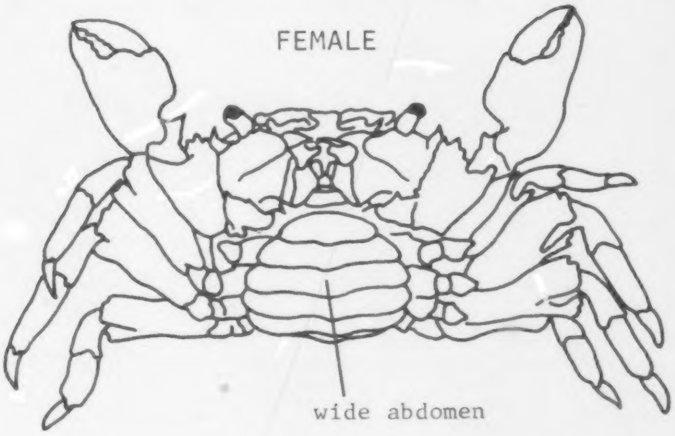
Look at the abdomens of all the crabs (of the same species) collected by the class. Do some crabs have wider abdomens than others? Which do you think would have the wider abdomen, males or females? Why? How to you think the abdomen is used?

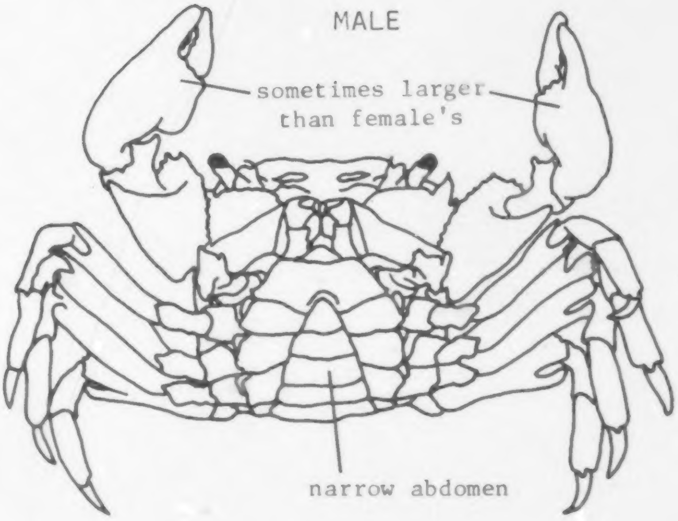
Gently lift up the abdomen on a male crab and on a female crab. Is there a difference in their little "hidden legs"? Which has more? Why?

Suggested Procedures.

It usually is possible to distinguish male from female crabs. Males of some species have noticeably larger claws. The female abdomen is quite broad compared to the male abdomen. If the abdomen is gently lifted away from the rest of the body one can see the small appendages. There are fewer of these abdominal appendages in males than in females, and several are fused in the male to form a copulatory organ.

Perhaps the class will be lucky enough to find a female carrying a mass of eggs, or "sponge" as it is called, tucked under her abdomen, and held in place by her more numerous abdominal legs.


FEMALE
wide abdomen


MALE
sometimes larger than female's
narrow abdomen

Problem 9. ROCK CRAB BEHAVIOR (Classroom)

BANDS 2, 3

General behavior of rock crabs has already been observed in the field. This problem extends the observations to the classroom where more time can be given to details and the action of the small claws can be seen.

Materials.

- *Several trays of rock crabs*
- *Algae-covered rocks*
- *Plastic drinking glasses or glass jars*

Problems:

How do crabs move? Do they walk or swim? In which direction do they usually move? Can you cross your hands at the wrist and demonstrate the crab's movement?

Do crabs stay in the middle of the tray or near the sides? Which way do they face?

Into the crab tray, place some algae-covered rocks taken from the place where the crabs lived. How do the crabs behave toward these rocks?

An animal may respond to many types of stimuli in order to find a proper shelter. Are the crabs responding to the desire to be under something (i.e., does it like to feel something around it or on its back)? or to the desire to be in a dark place? or both? Can you test your idea? Can you think of something that will provide the crabs with something to "snuggle" under, or next to, but will let in light?

Watch a crab closely as it moves on a rock. What is it doing with its claws? (gathering the algae that grows on them for food)

After the crab has been in the tray for a day or so, you will begin to notice small pellets scattered around the bottom of the tray. What are these?

Suggested Procedures.

Nearly all true crabs walk sideways. Have the students cross their hands at their wrists and move them sideways. The "legs" (fingers) in the forward position grasp the substrate and pull, while the "legs" in the rear position push off the substrate.

In investigating the crabs' use of rocks as shelter, the students may have ideas on how to proceed. If they get stuck, you may want to try these steps:

1. Give the crabs in Tray #1 only rocks.
2. What will happen if we give them glass jars in Tray #2?
3. What if we give them rocks and glass jars in Tray #3?
4. What are our results? What conclusions can we draw from our experiment? Do the crabs seem to be seeking just something to be under? Or does it have to also be a dark place? Here is a data sheet that may be used with BAND 3 students if they cannot devise their own.

TABLE 1. Response of Crabs to Rocks and Similar Objects

Tray No.	Description	Crabs' Response
1	rocks	
2	glass jars	
3	rocks and glass jars	

Further Behavioral Observations of Rock Crabs. Many technical studies have been done on the behavior of various species of rock crabs. These crabs often have a whole repertoire of behavioral activities; in one study, these were reported in this manner:

Stationary (sitting, standing, posing, sleeping)
Locomotory (walking - back, forward, sideways, running, jumping, swimming, burrowing)
Feeding (feeding, carrying food)
Cleaning (foam-bathing, grooming, egg-caring)
Elimination (defaecating, regurgitating)
Flight (submissive posturing, fleeing, circling)
Aggression (pushing, signaling, chasing, killing, low threatening, high threatening, striking - low and high)
Reproductive (waving, stroking, positioning, copulating)

Although crabs may remain stationary for long periods of time, some of the above actions may be observed if trays of crabs are maintained in the classroom over a long period of time. Interested BAND 3 students may be made responsible for maintaining the crabs with fresh water and food as well as making careful observations and notebook reports on their behavior. Careful observation may center on such questions as:

-Does the same crab always return to the same area, i.e., do these crabs show territoriality?

-Are the crabs more active at some times of day than others?

-Do the actions always follow in the same order?

-From the time the school day starts to the time it ends, exactly what are the crabs doing? How much of this time do they spend on each activity? (Maybe station "observers" at the crab tray; each student being assigned to a specified 20-minute "watch".)

Problem 10. COLOR CHANGE IN ROCK CRABS BANDS 2, 3

If, when planning ahead, you note that you will include this topic among your experiments, then set up crab pans in the previous experiments with vari-colored backgrounds. This will produce some color variation which can be noted when first presenting this problem.

An alternate plan is to leave all the crabs dark and have the students predict whether or not a change of background color will produce alteration in the color of the crab.

Materials.

- *-Two transparent trays with several rock crabs in each (see Suggested Procedures, #2 below)*
- *-Black paper*
- *-White paper*

Problems:

Will rock crabs change the intensity of their color?

Is your crab the same shade of color as when you collected it? If not, why do you suppose it has changed?

Can you think of an experiment to test your idea?

Suggested Procedures.

Crabs may show a lightening when they are moved from dark rocks to a lighter colored background.

Transparent trays (e.g., glass or plastic) are best because it is an easy procedure to change the intensity of the crabs' background: simply put a piece of white or black paper underneath the tray. If transparent trays are not available, perhaps pieces of white or black plastic garbage bags could be used inside the tray to change the background.

The students may have their own design for an experiment. If they need a suggestion, you might try something like this:

1. Place a few crabs and rocks in each of three transparent trays.

2. Keep Tray #1 on whatever surface it usually is on; this is the Control Tray. By having a control, if any changes in color intensity occur for any reason other than background (e.g., tidal cycle, disease, etc.), it will be evident in the control.

3. Put Tray #2 on black paper, and Tray #3 on white paper.

4. Compare the intensity of the crabs' colors every day. After three or four days, students should be able to see a difference among the crabs. Older students can keep a journal, perhaps including a data sheet something like this:

TABLE 2. Color Changes in Crabs

Date	Tray #1 Control Background	Tray #2 Black Background	Tray #3 White Background

Teacher Background.

Crabs sometimes lighten or darken their body color. Some species of crabs follow a daily rhythm, lightening their body by day and darkening it at night. It may be impossible for students to look for this diurnal color change unless they return to school at night or are allowed to take the crabs home.

Some rock crabs seem to change their color intensity to conform to their surroundings. If they are removed from dark rocks and put against a light background for two or three days, they change to a lighter shade. This behavior seems to have survival value; if they resemble their background, they may escape their predators.

SWIMMING CRABS (PORTUNIDAE)

Introduction.

People often use small, red-meshed nets to catch swimming crabs in shallow water near stream mouths. They may be catching one of these three species:

Crab	Front Margin Between Its Eyes	Side Margin of Its Back	Other Comments
Samoan	toothed	rounded	very thick claws
Hawaiian	smooth	pointed*	very long eyestalks
White	toothed	pointed*	---

*See picture in first part of this lesson.

These three species of swimming crabs are good to eat. To protect them from being over-collected, the Hawaii Fish and Game Division has made a regulation that crabs cannot be collected using nets with mesh less than 2 inches. This regulation allows young crabs to grow up and reproduce. Students may collect small specimens of these edible crabs for observation while at the seashore but they may not take them back to the classroom. Big specimens caught in a crab net with mesh greater than 2 inches are probably too big for class aquaria.

Other species of swimming crabs may be caught, and, depending on size, kept in the class aquarium. Watch out, though. Swimming crabs are active predators. They may quickly depopulate your aquarium! (A scientist has reported that one species can even catch mole crabs, by digging them, corkscrew-fashion, out of the sand!)

Problem 11. CAPTURE AND OBSERVATION OF SWIMMING CRABS BANDS 1, 2, 3

Crabbing with red mesh nets is a skill some of your students may already have, in which case they can take over this class. Parents, relatives, or neighbors are frequently a good source of outside help in capturing, identifying, and handling the larger edible crabs.

Materials.

- *Red mesh crab net*
- *Bait (fish head or other scrap meat)*
- *Transparent plastic bags with twisties*
- *Large, transparent plastic box or bucket*

Problems:

Capture a crab in a crab net. (See procedure below.)

Compare the appearance of this crab with other crabs you have seen.

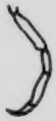
Examine the pincers but be careful of them. They can give a hefty bite.

Examine the rear legs. These tell you whether it is a swimming crab or a walking crab. How?

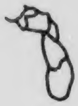
Look for small swimming crabs in tide pools and on reef flats.

Which direction do crabs swim? sideways, forward, backward, all ways?

Put the crab in a bucket or pan with sea water. Can you see water moving near the crab?



The last pair of legs of a walking crab are pointed.



The last pair of legs of a swimming crab are flattened like a paddle.

Suggested Procedures.

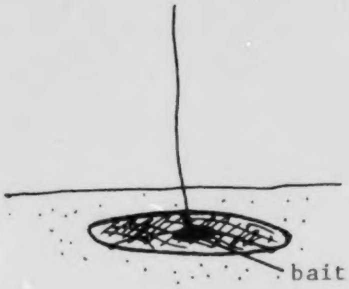
Small, non-edible, swimming crabs may be collected from tide pools during a field trip.

One or two of these may make an interesting addition to the class aquarium so long as they obey Reed's Second Law and do not cannibalize everything else in the tank.

Many children in Hawaii are adept at catching larger swimming crabs with red mesh nets, which may be purchased in many local stores.

Lower the crab net by a rope into waters likely to contain swimming crabs such as at stream mouths.

Let the net rest on the bottom with bait (a fish head or other piece of meat) tied securely in the center of the net.

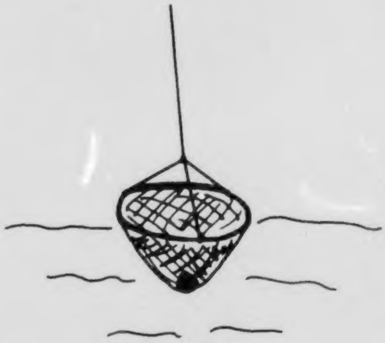


Net on bottom.

After about half an hour, lift the net and harvest the crabs contained in it.

Once caught in a net, crabs tend to hold tightly to the mesh with their claws. (Watch out for these claws; they're fast and would hurt if they pinched someone.)

Partially fill a strong transparent plastic bag with sea water, and put the crab and the part of the mesh it is holding inside the bag. Hopefully, in a short while the crab will relax its grip on the net which can then be pulled out of the plastic bag. Close the bag with a twisty.



Net being pulled up.

The crab can now be passed from student to student for observations. A fairly large transparent plastic box may also be a good way to contain these crabs while they are observed by the students.

Call attention to the paddle-like swimming legs and to other parts indicated in Problem 7 for rock crabs. Count the legs.

A swimming crab's body plan is streamlined for swimming sideways. The claw on the leading side is often bent with the "elbow" acting like the bow of a boat as it breaks the water; the legs on the stern side trail behind in the wake.

Problem 12. INTERNAL CRAB ANATOMY . . . AND CRAB SALAD BANDS 2, 3

This activity usually has to be done using crabs purchased from the market. Children often object to eating their crab "frinds" whom they have caught and studied in class. We have been generally unsuccessful in convincing them that the crabs purchased for food from the market are the same as the crabs living in the ocean and might be used for the same purposes.

Materials.

- *Several swimming crabs obtained from a seafood market (enough to prepare crab salad for everyone to have a little on a cracker)*
- *Saltine crackers*
- *Bowl*
- *Mayonnaise*
- *Mail scales (optional)*

Problems:

What does a crab look like inside?

Perhaps you can find the heart and stomach, with your teacher's help. Where are they in relation to each other? in relation to where yours are inside of you?

If you have looked at the inside of a clam or oyster, perhaps you remember what the gills looked like. Can you find gills inside the crab? Have you noticed the water currents around a living crab? What function do gills serve in crabs, clams, oysters, and some other animals?

Which part is the crab's muscle? Where else besides the main body would muscles be found? (legs) Muscles are the part that is especially good to eat.

(cont'd on next page)

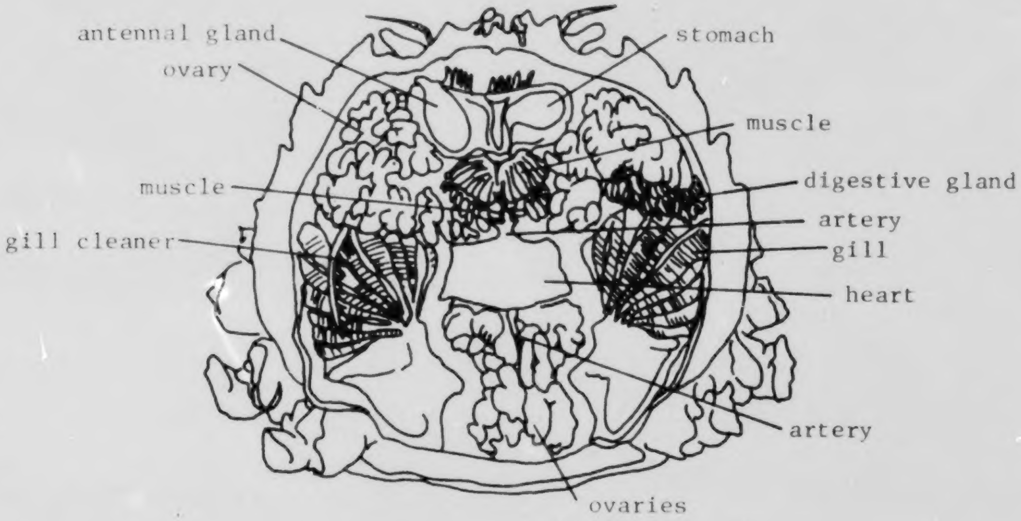
Problems: (cont'd)

Make a crabmeat salad by mixing the crabmeat with mayonnaise in a bowl. You may want to serve it on crackers. How does it taste?

Was the skin of the crabs hard and crusty? Did any crabs have a softer, more flexible skin? If so, why do you think it is soft?

Suggested Procedures.

1. The crabs should be cooked ahead of time. Keep the cooked crabs on ice or in a refrigerator until time for class use.
2. Have students examine the crabs with clean hands and utensils, so that they can make a salad to be eaten.
3. Open the crabs by removing the back. Students need not carry out a detailed study of crab anatomy, but here is a diagram for the teacher's background:


antennal gland
stomach
ovary
muscle
digestive gland
muscle
artery
gill cleaner
gill
heart
artery
ovaries

CRAB INTERNAL ANATOMY, DORSAL VIEW

4. Remove the crabmeat from the body and legs.
5. Perhaps older students could decide how "economical" crabmeat is:
   a. Find out how much the crab cost.
   b. How much does the meat weigh?
   c. What is the cost per pound of crabmeat?

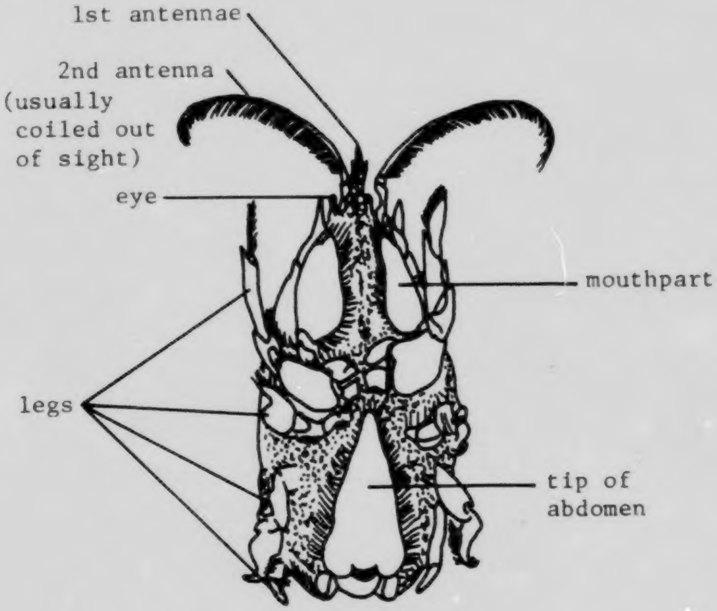
d. How does this cost compare to other supermarket meats, e.g. hamburger? How economical is crabmeat? Would it be cheaper if you caught your own crabs? (But you would have to figure in the cost of a crab net and license!)

6. In amongst the crabs from the seafood market may be a soft-shelled crab. This may be an opportunity to discuss crab and shrimp growth; see Problem 18.

SAND "TURTLES" or MOLE CRABS (HIPPIDEA)

Introduction.

Animals belonging to this family are not true crabs. After seeing true crabs such as swimming, rock, and ghost crabs, the body plan of a Hippidean is noticeably different.

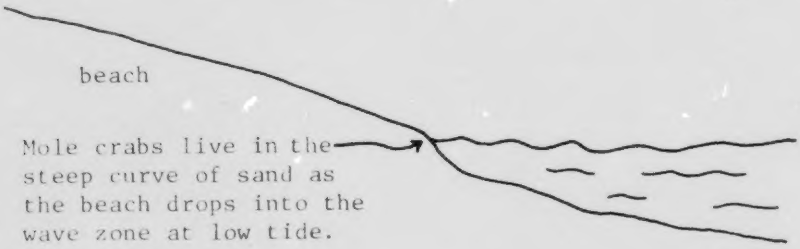


SAND TURTLE, VENTRAL VIEW

See illustration of the Hawaiian mole crab in the first part of this lesson.

When mole crabs are resting, almost all their appendages are tucked under their carapace, out of sight as viewed from the top. In this way, they resemble a turtle that has withdrawn in its shell; hence, one common name for this crab is sand turtle. Their rounded body is very appropriate to their habit of burying themselves in sand. The fact that they burrow probably accounts for their other common name, mole crab. However, a mole burrows frontwards; a mole crab burrows, swims, and crawls backwards. (Some species of this crab hold their two first antennae together, giving the impression of having a pointed nose, like a mole.)

Sand turtles, as they seem to be more commonly called, live in sandy beaches where the waves are constantly washing over them. They require clean, well-aerated water, and so are not as common along beaches where the water is always calm. They spend most of their time buried in the sand, with only their small first antennae, eyes, and sometimes two front legs protruding. These antennae form a tube for water to be drawn in and passed over the gills for breathing. The ends of the legs have sensitive tips for detecting food.



Mole crabs live in the steep curve of sand as the beach drops into the wave zone at low tide.

Problem 13. CAPTURE AND OBSERVATION OF SAND TURTLES (field work) BANDS 2, 3

Scooping up mole crabs from a sandy beach is not always as easy as the literature on the subject leads one to believe. Search for mole crabs during a field trip to the beach. If they are there, this lesson can proceed. Often it is necessary to search again on another day or another beach. When they are found, they create sufficient student excitement to have been worth the search.

Materials.

-Hand garden rake or small shovel
-Sieve box (as illustrated in Problem 2)
-Bait (fresh fish) secured to a small stick

Problems:

Collect some mole crabs from the beach either by digging them out or luring them out.

Observe their body shape, number and arrangement of legs, antennae and mouthparts.

Suggested Procedures.

Capture:

First of all, contaminated beaches and beaches having still waters are not likely to have mole crabs. On a clean, wave-washed, sandy beach, look for mole crabs at low tide.

Sit quietly as close as possible to the water line, perhaps in the water at the wave break zone.

Observe intently the sand at the "hump" of the beach where it dips into the water. This is where the mole crabs rest beneath the surface of the sand with only their eyes and antennae protruding. Their size and color render them nearly invisible.

As a wave retreats, observe the surface of the sand. Look for two tiny V-shaped currents produced by the interruption of the receding wave by the protruding eyes and antennae. That is the spot to dig . . . fast!

Even if no evidence of mole crabs are visible, dig anyway, shoveling the sand through a screen to see if any mole crabs can be extracted.

About every hour or so, a mole crab emerges from the sand, rides a wave up the beach, then slides back again with the wave. A sharp eye might see one.

Tie a piece of fresh fish to a stick of sufficient size to anchor the meat in the sand. Wait and watch from a short distance away for a mole crab to be lured from its hiding place and come for the bait.

Observations:

Have the students compare the shape and appendages of a mole crab with that of a true crab, noting particularly the rounded body and feathery antennae of the mole crab.

Males and females are not as easily distinguished as in the true crabs. Male sand turtles are much smaller than females, and lack three pairs of abdominal appendages. Perhaps you can see an oval, bare spot surrounded by short, stiff hairs on the last segment of a male's fourth pair of legs. This serves as a suction pad to clasp the female during mating.

More detailed observations on these crabs are more easily done in the classroom as indicated in the problem below.

Problem 14. CLASSROOM MAINTENANCE AND OBSERVATION OF SAND TURTLES

BAND 3

Unlike other crabs, most of which are scavengers, mole crabs are exceedingly sensitive to pollution. In fact the presence of mole crabs on a beach is an indicator of uncontaminated sand and water. This is an important key to their successful classroom maintenance.

This is a problem for advanced elementary students.

Materials.

- *Mole crabs*
- *A plastic dish pan set up with clean beach sand and several air-stones and/or a good subsand filtration system*
- *Bits of fresh fish or frozen shrimp for food*
- *A glass baking pan for observation from the bottom*

Problems:

Classroom habitat:

What kind of habitat should you prepare for sand turtles, based on the kind of place in which they live in nature? Set up such a habitat for a few mole crabs.

Feed and maintain them in a healthy condition.

Observe the mole crab's appearance:

Which end is which in this animal?

Why do you suppose some people call this a sand "turtle"? Hint: Look at it from the top (i.e., look down on the back).

The feathery, second antennae are usually coiled up underneath the trap-door-like mouthparts. Watch for a time when the antennae are uncoiled and sticking out of the sand, or, on a dead mole crab use your pencil tip to uncoil and observe the antennae.

Observe the mole crab's behavior:

Why do you suppose some people call this a "mole" crab? Hint: What happens when you put this crab in wet sand?

Try turning several crabs on their backs in your hand. Some of them "play possum". What does that mean? Why do you suppose they do it?

(cont'd on next page)

Problems: (cont'd)

Put some sand turtles in sea water in a glass baking pan with about one inch of sand on the bottom. In which direction do they swim, burrow, or crawl? By observing through the bottom glass, can you see with which part of their body they dig?

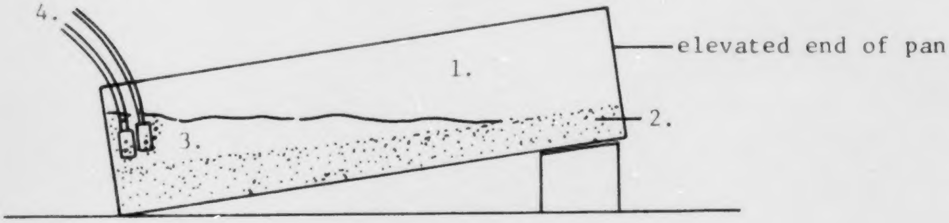
Observe their position in the sand after they have been left undisturbed for a time. Will the crabs stick parts of their body out of the sand? Which parts? For what reasons?

It is important for this crab to stay in the wave zone. If it gets stranded too far up in this zone, away from the reach of waves, how would you think it would know which way to go in order to find the water again? How can you test your hypothesis?

Suggested Procedures.

Classroom habitat:

Students who have had experience and success keeping other animals alive, may want to experiment with sand turtles, trying the following or similar technique.



1. Large plastic dishpan or similar, non-metal container set at an angle.
2. Clean beach sand at a depth of several inches.
3. Clean sea water which more than covers the sand at the lower end of the pan, but does not cover the wet sand at the upper end of the pan.
4. Actively bubbling air stones. A sub-sand filter with a bubbling pipe recycling water through the sand would also be useful.

To feed the crabs, place a few small pieces of fresh fish or frozen shrimp on the sand. The mole crabs will scurry out of the sand to retrieve them. Remove all uneaten bits before they have time to contaminate the pan.

In nature, there seem to be two methods of feeding. Using their feathery antennae, sand turtles filter food particles and plankton out of the water. At other times, they are more predaceous, grabbing very small animals in the waves. Sand turtles have often been seen eating Portuguese Man-of-War jellyfish by pulling them down into the sand with them!

Behavior:

Sand turtles (and 'possums) may play dead to make predators think they are dead, and so not eat them.

In order to help the students formulate a hypothesis as to how a stranded sand turtle could get back to the wave zone, you may want to use these hints:

1. Is there a slant to the beach?
2. If you took a walk up a mountain, and got lost, how would you know how to get home?

Sand turtles show a preference for going downhill rather than uphill; this behavior would move them toward the ocean from a stranded location. Using the glass pan and moist sand, the students may be able to prove their hypothesis.

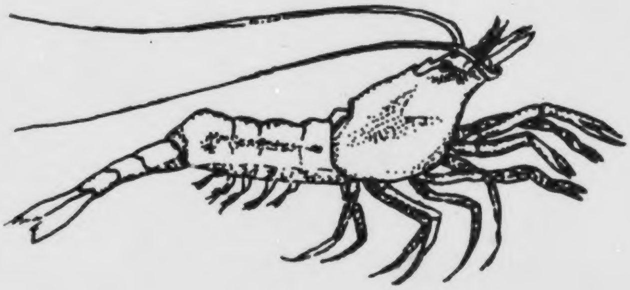
Placing a few sand turtles in shallow sand in a glass pan permits observation from below of their digging motions.

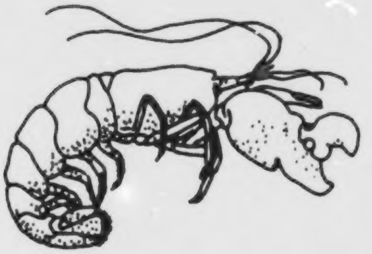
SHRIMP

Introduction.

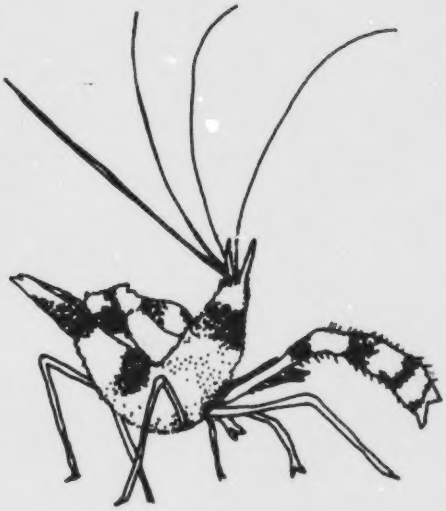
Just as there are many kinds of crabs, there are also many kinds of shrimp. There are four types that may be found commonly by students.

True Shrimp. The diagram shows a generalized shrimp anatomy. May be found almost anywhere; look for them among limu, around dock pilings, and in tide pools.

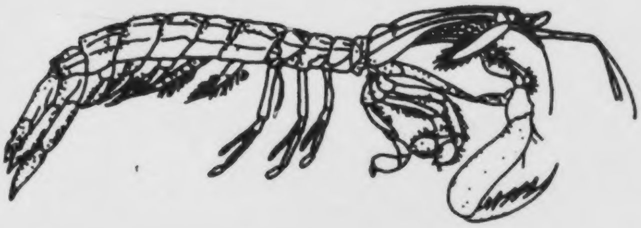




Snapping Shrimp. Has one leg on one side modified to form a large, distorted claw. May be found in burrows in coral heads, but perhaps easier to get specimens that live in sponges attached to dock pilings.



Banded Coral Shrimp. Third pair of legs thickened and lengthened to form claws; red and white bands on body and claws. May be found in crevices in low tidal zone and deeper in coral reef flats.



Mantis Shrimp. Flattened top-to-bottom more than true shrimp. Second pair of legs modified to form powerful, jack-knife or crusher claws. May be found in burrows in intertidal zone; under rocks; sometimes found in limu.

Note: Even small mantis shrimp can be dangerous, and larger ones should definitely be avoided. The claws can spear a finger or at least give it a bad bruise. The strike of the mantis shrimp is one of the fastest animal movements known.

Problem 15. GENERAL OBSERVATIONS OF SHRIMP

BANDS 1, 2, 3

For elementary students, whatever shrimp (and there are many kinds) which can be collected from tidal pools and the reef flat during a field trip, form the subject of this investigation.

Materials.

- *Net (to catch shrimp in water; not needed to get shrimp out of limu stranded on beach)*
- *Magnifying glass(es) for small shrimp specimens)*
- *Glass jar, or transparent plastic sandwich bag, or bucket with battery pump to hold shrimp for observation and transport back to the classroom*

Problems:

Look for shrimp in tide pools and in clumps of sea weed. Shake a rock or clump of sea weed in a bucket of sea water to see if any shrimp come out. Look small! Dig in muddy areas also.

How does a shrimp look similar to a crab? How does a shrimp look different from a crab?

Count its legs. Observe its mouth parts. Note the shape of the abdomen.

If you have more than one shrimp of the same species, perhaps you can see the difference between males and females. Hint: look at the swimming legs.

How does a shrimp move and in which direction? Which legs does it use? How does it move its tail and abdomen? How does it walk? How does it swim?

What color is the shrimp? Why do you suppose the shrimp is this color? Hint: what color is the limu or other area where it was found?

How can you test your hypothesis as to the reason for the shrimp's color?

Suggested Procedures.

Assist the students in observing shrimp anatomy with the help of the diagrams above and the Teacher Background notes below. Also recall the general introduction on crab and shrimp differences of the beginning of this topic.

Transport shrimp to the classroom aquarium in buckets. As with any aquatic animal, put enough water in the bucket to just cover the shrimp. In this way, there is a large surface to small volume ratio, permitting maximum transfer of oxygen into the water.

Shrimp can be kept routinely in the aquarium. For closer observations, they can be netted and transferred to smaller containers (glass jars, or transparent plastic cups or bags).

Shrimp can serve either as predators or scavengers: some large shrimp (e.g., the banded coral shrimp) may eat other, smaller animals in the aquarium, or they will eat pieces of raw fish. Small shrimp may be eaten by their bigger brethren!

For experimenting with color changes, isolate one or several shrimp in each of several aerated containers of sea water. Put different colors of limu in each container; you may have three containers: a red one, a green one, and a brown one.

BAND 3 students can record their results in notebooks.

Amphipods or isopods (see Teacher Background on Crab and Shrimp Cousins), found in limu may also be used for this experiment.

Teacher Background.

A shrimp has 10 "walking" legs, like a crab. But a shrimp also has its 10 abdominal, swimming "legs", called "swimmerets", readily visible. So the students would be accurate if they decided that shrimp are 20-legged. However, scientific usage restricts the classifying of shrimp to the walking legs. So a shrimp is a decapod too.

The first pair of swimming legs on a male are modified to form a copulatory tube when held together. The same pair on a female is much reduced.

Some shrimp are almost transparent (which helps make them appear invisible to predators). Others are brightly-colored, sometimes corresponding to their backgrounds. If you have a magnifying glass, look closely at the colors of a shrimp.

Shrimp get their colors from various sources. Yellow and green originate from their plant food, while red, brown, white, and blue are manufactured by the shrimp itself.

The pigments are often located within special cells, called chromatophores, in the shrimp's skin. Different colors may be isolated into different cells; in some cases, several pigments occur in the same cell, but only one may be expanded at any one time.

Colors in shrimp are used for many purposes. They may help species to recognize one another; color changes at reproduction time may attract the opposite sex; and appropriate colors often camouflage a shrimp and therefore protect it from enemies.

Problem 16. SNAPPING, IN SNAPPING SHRIMP BAND 3

Have you heard crackling sounds as you walk along a muddy shore at low tide? The sound resembles a popcorn machine going full tilt, or a Lilliputian pistol war in progress. Snapping shrimp, sometimes called pistol shrimp, are very common in Hawaii. A snapping shrimp in the aquarium can make a noise loud enough to be heard throughout the classroom.

Materials.

- *One or more snapping shrimp obtained during field trip*
- *One or more small containers with sea water*
- *Magnifying glass*

Problems:

Have you ever heard a sound like corn popping while you walked along the beach at low tide, or were swimming under water? If so, search out the source of the sound and find the shrimp that are making the noise. Bring a few back to your class aquarium.

Can you see what part of the body makes the snapping noise?

Why do you suppose this shrimp makes this noise?

Suggested Procedures.

Guided by their ears, let the students search out the source of the popping noise heard at low tide. It may be difficult to get a close look at a snapping shrimp's claws. Perhaps you could try one of these techniques:

1. Wrap a specimen in a sea water-soaked paper towel strip and examine the claw with a magnifying glass.

2. Look at a snapping shrimp molt (see Problem 17).

3. Suggest students check a library book for a good close-up photo or diagram of a snapping shrimp.

Teacher Background.

The sound made by snapping shrimp is produced when a knob on the finger of the large claw is forced into a socket as the claw is snapped shut.

Apparently, the sound frightens away predators; perhaps it also warns another snapping shrimp that a burrow is already occupied. The claw may also be used to secure food.

ADDITIONAL INVESTIGATIONS ON CRABS AND SHRIMP

Introduction.

Three topics likely to catch the attention of elementary students have been selected to go under this heading. These by no means exhaust the possibilities for study. Students whose interest has been captured by the arthropods of the sea will think of many more ideas they will want to investigate on their own with a little help and encouragement from their mentors.

Problem 17. CRAB AND SHRIMP GROWTH BANDS 2, 3

Investigation of this problem will suggest itself naturally when a student discovers what at first appears to be an extra, or dead, crab or shrimp in the aquarium, but which turns out to be an empty skin . . . a molt.

The questions and suggestions in the problem below can be used or modified according to student age and the appeal to them of the phenomenon of molting.

Materials.

- *Crab, or shrimp, that has just molted*
- *The animal's molt*

Problems:

Ever since you were a baby, you have been growing bigger. You will continue to grow bigger until you become "grown Up". How often do you grow? Do you grow gradually all the time? On some days do you, all of a sudden, grow an inch or two?

What if your skin were like a tight, non-stretch, piece of clothing which you could not take off. How could you grow?

What kind of skin do crabs and shrimp have? Notice that it is stiff and will not stretch. How can crabs and shrimp grow? Form a hypothesis of how crabs and shrimp could handle this problem.

(cont'd on next page)

Problems: (cont'd)

Can you find any evidence from your observations which will support your hypothesis?

. . . Discussion . . . Investigation . . .

Shedding of a skin by an animal is called molting. The skin which has been shed is called a molt.

Gently spread out a molted skin from a crab or shrimp on a piece of stiff paper or cardboard. Examine it carefully, if possible with a magnifying glass.

Does the skin have any color? Look at the eyes.

The old skin that is left behind does not go to waste. It is a rich source of protein and minerals. Some animals eat their own molt to get back some of these proteins and minerals. Otherwise, various scavengers of the ocean quickly make a meal of an old crab or shrimp skin. A crab or shrimp in the class aquarium may molt, and the molt may be eaten, even before anyone notices!

Where is the opening that the living crab or shrimp came out of?

How big is the skin? How big is the crab or shrimp? Has the animal grown since it has shed its skin?

Keep the skin in a safe place so that it will not blow away or get crushed. Measure it. Keep a record. Record the date.

When do you think the crab or shrimp will molt again? Watch for when it does, record the date, and the size of the new molt.

How fast do crabs and shrimp grow?

Suggested Procedures.

The directions in the box (adapted by the teacher as feasible) are self explanatory but the following additional points may be useful.

In spreading out the molted skin to dry, a small brush may be found to be useful in arranging the legs and antennae in a natural position. A light covering of cloth or paper during the drying stage will keep dust from accumulating on the specimen.

After the molt has thoroughly dried and stiffened in its life-like position, it can be glued to a new mounting paper, labeled, and dated.

Adult crabs molt as infrequently as once per year. Young, actively growing, and well fed crabs and shrimp in our test tank molt about once per month. By working with juvenile, actively growing animals and measuring the increased size of each molt, the students can calculate growth as so many mm per month.

Students with sufficient sophistication and experience to do this investigation have the ability to produce a reputably written and illustrated science notebook report.

Teacher Background Information.

Crabs and shrimp (and insects, spiders, centipedes, and similar animals) belong to a group of animals which have crusty skins. This skin serves as a skeleton for the animal and resembles a suit of armor; it is hard, with flexible joints. In order for the crab or shrimp to grow, it must periodically shed this skin, a process called "molting".

To begin the process of molting, a crab makes a new, soft skin under its old skin. The old skin is softened by reabsorption of the calcium salt along the lines where the skin will split (in shrimps, lengthwise down the topside of the abdomen; in crabs, crosswise, just behind the "back").

Prior to the actual shedding of the skin, the animal will often seek a secluded spot where it will be relatively safe from predators when it emerges with a soft skin. Next, a lot of water is absorbed; the old skin splits open, and the animal pulls itself out! It is now a soft-bodied crab, and it can grow!

During the final phase of molting the animal hardens its new skin by extracting calcium out of the surrounding sea water and depositing calcium salt in the skin.

The old skin that is left behind does not go to waste. It is a rich source of protein and minerals. Some animals eat their own molt to get back some of these proteins and minerals. Otherwise, various scavengers of the ocean quickly make a meal of an old crab or shrimp skin. A crab or shrimp in the class aquarium may molt, and the molt may be eaten, even before anyone notices!

Problem 18. CRAB AND SHRIMP YOUNG

BAND 3

This problem is suggested for BAND 3 students, or those who have been successful in maintaining crabs in the class aquarium and who can use a microscope. When to do this investigation is dependent on when a gravid female happens to be found.

Materials.

- *-Female crab, carrying egg mass*
- *-Aerated container of sea water, separate from the class aquarium*
- *-Dissecting microscope*
- *-Medicine droppers*
- *-Brine shrimp hatchery (optional)*
- *-Fine mesh net (optional)*
- *-A supply of clean sea water*

Problems:

After finding and successfully transporting a female crab or shrimp carrying eggs back to the classroom, put it in a secluded corner of the aquarium. You may want to "fence off" a corner, using rocks, coral, and/or a small plastic basket such as those used for strawberries or cherry tomatoes.

What color are the eggs? (This is how to tell their age.)

Take a small sample of the eggs and look at them under a dissecting microscope. What do they look like? Check a sample of eggs each day.

How long does it take for the eggs to hatch? What color were they just before they hatched? What color are the new young?

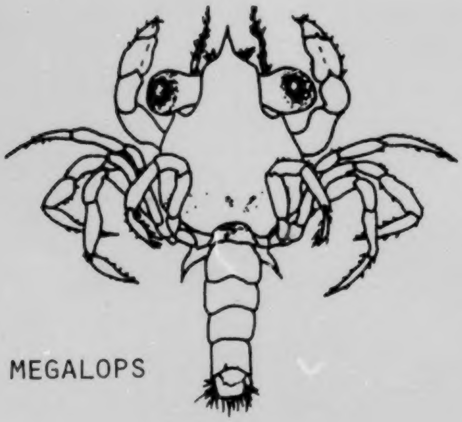
Capture a few of the young that have hatched out. What do they look like?

A general name for small, young lower animals, such as insects, crabs, and even tiny fish, is larva (plural: larvae). A special name for baby crabs and shrimp is zoea (pronounced to rhyme with "go-see-ya"). A very young crab with big eyes and extended tail is called a megalops. Megalops means "big eyes". Later the tail and abdomen get tucked under the head-chest region as in adult crabs.

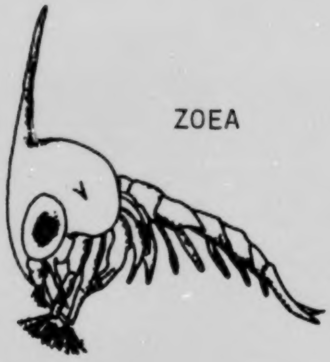
Can you think of a way to take care of the larvae? What should you feed them? Give them their own container (for protection from larger predators) and watch them grow. Why do only a few of them grow up? What would you have to do to get all of them to survive?

Keep data on amounts, sizes, and times of growth and molting.

Make a science report of your experiment.



MEGALOPS



ZOEA

Suggested Procedures.

As the crab eggs turn from orange to dark brownish, transfer the crab or shrimp to a separate, aerated container of sea water. Otherwise, the larvae that hatch out may be lost in the large class aquarium. The developing eggs need very clean water. The sea water may need to be changed often (e.g., every day or every other day).

Students should write down their daily observations, including drawings of the developing eggs and larvae.

Elementary school children can try keeping alive crab and shrimp larvae, and watch them grow each day, if they can accept the expected high larval mortality. Even in optimal laboratory conditions - even in the sea - many, many larvae do not live to become adults. (After all, part of their function is to serve as food for other animals in the sea.)

Short-term laboratory maintenance of larvae is not difficult. Keep the larvae in their own unaerated container of sea water. (If aerated, the larvae will get stuck at the surface of the water.) Young crab and shrimp larvae will eat each other. Therefore, some of them can be kept alive for at least several days with no external feeding.

Long-term laboratory maintenance is more difficult. Indeed, the whole scientific field of mari- or aquaculture is devoted to the successful rearing of edible marine animals. The larvae must be cared for daily:

1. Feed them young brine shrimp. Hatch brine shrimp in their own jar. Brine shrimp eggs, with hatching directions can be purchased wherever aquarium supplies are available.

2. Change their sea water. Pour the larval culture through a very fine mesh net. The larvae caught in the net should be quickly put into new sea water.

Teacher Background.

As indicated in Problem 8, crabs and shrimp are either male or female. At various times of the year, males clasp females and copulate. A female crab or shrimp carries the developing eggs glued to her legs, inside her abdominal "pouch" in crabs, or under the abdomen in shrimp. In crabs, the mass of eggs is sometimes called a "sponge"; a shrimp is said to be "in berry", a very descriptive phrase. When first laid, the eggs are orange, indicating a large amount of yolk present. As they near maturity, the eggs become darker, finally hatching into microscopic larvae that disperse in the sea water.

Although these larvae have legs and can make jerky swimming motions, they depend upon ocean currents to move them around. During the weeks that it is a passenger of the sea, a larva grows, molting many times. At first it looks like a funny, shrimp-like clown with big eyes and a pointed head (zoea stage; "zoea" means life). After one of its molts a crab larva assumes a new shape; it resembles a miniature crab, except that its abdomen sticks out behind instead of being tucked underneath. Shrimp do not have a megalops stage; instead, they have different kinds of zoeal stages.

At the end of the second stage, the larva begins to settle out of its floating, or "planktonic", lifestyle and seek the environment typical of its species. After its last larval molt, it finally becomes a small, adult-looking crab or shrimp, although it may be several more molts before it becomes mature.

Problem 19. CRAB AND SHRIMP COUSINS BANDS 1, 2, 3

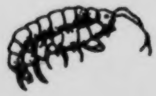
There are many crusty-skinned cousins of crabs and shrimp that live in the ocean. In fact, these "crustaceans" have been called the "insects of the sea" because there are so many different kinds of them. In fact, insects, crustaceans, and their near relatives belong in the same Phylum, Arthropoda.

No specific investigations are detailed for this problem. Diagrams and a few notes are given for a few crab relatives commonly seen in Hawaiian tide pools. These may assist with identification. Investigations might be developed by teacher or students if and as opportunity and interest arise.

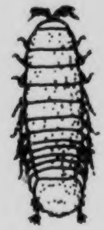
Amphipods.

If you lift up some limu that has been stranded on the beach, little "beach hoppers" may startle you.

As tide pool rocks, mud, and sea weeds are sorted out, very tiny shrimp-like creatures may be noticed escaping into the bucket or sorting jar. These side-ways flattened animals are "amphipods". With a magnifying glass, perhaps you can see the two kinds of legs, the reason for their name.



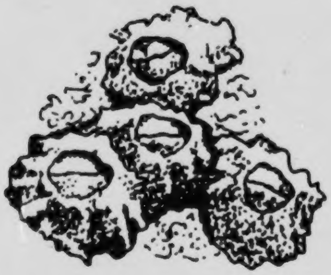
Isopods.



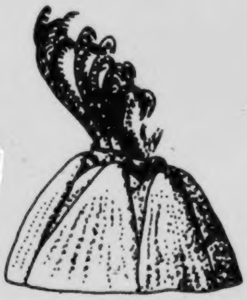
"Isopods" are small, flat, oval, crustaceans which sit close to the substrate. Their counterparts on land are called pillbugs. If you look closely, they live up to their name of having all similar legs. Some species inhabit intertidal areas. Another genus functions as termites in the sea; so you may see them if you break open some wood that has been in the ocean for a while. Still other isopods are skin parasites on fish.

Barnacles.

Look closely at rocks in or near the ocean at low tide. Can you see the white, volcano-like bumps? The animals living inside these limestone "castles" were originally thought to be strange sea shells. But put a small rock covered with these "barnacles" in your aquarium and see what happens! Top plates of the limestone house will open up and out will sweep many slender, jointed legs!

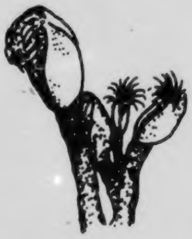


ACORN BARNACLES



OPEN BARNACLE

The young barnacles are free swimming but after a short, floating larval period, this animal glues its neck to a rock, or other hard substrate, and makes itself a limestone house that lasts the rest of its life.



A sea-going cousin of the barnacles is often seen attached to any object, natural or man-made, that has washed ashore from a period adrift on the open ocean. These animals have a much skimpier covering of limestone plates atop a tough, fleshy, sometimes long stalk. They are aptly named "goose neck" barnacles.

How many other crusty-skinned crab/shrimp cousins can you find?!

5. BRITTLE STARS...SEA URCHINS...SEA CUCUMBERS

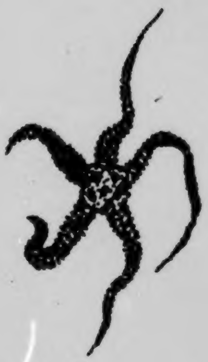
Introduction.

Phylum Echinodermata is comprised of related groups of spiney skinned animals having tube feet and usually a five-rayed radial symmetry. Of the five classes of echinoderms, the three types of animals studied here are representatives of classes commonly found in Hawaiian tide pools and reef flat areas.

The characteristics of the "spiney skins" are easily observable by amateurs. After investigating brittle stars, sea urchins, and sea cucumbers, the students should be able to deduce from their observations that most of them have body parts or markings arranged in five rows although in different "styles".

BRITTLE STARS

Brittle stars are members of Phylum Echinodermata, Class Ophiuroidea. Brittle stars have small central disks and five slender, graceful arms which may break off readily in combat or defense. This accounts for the name brittle star. They are also called serpent stars because of sinuous gliding motions which their flexible arms make possible.



BRITTLE STAR

Brittle stars are usually found several together under rocks or in crevices on the reef flat and sandy bottoms just below the low tide level. Brittle stars crawl about at night and hide under rocks by day. However in a tank which provides no hiding places the students can see them move about in the daytime. Their favorite food is shellfish but they will also pick up detritus and eat algae.

Problem 1. FIELD INVESTIGATIONS BANDS 1, 2, 3

During an Extended Field Trip at low tide, note whether the offshore bottom areas contain brittle stars in sufficient quantity for class observation. If so, this topic can be pursued at that time. Another approach is for the teacher to search for brittle star territory and at a convenient time conduct the class on a Short Field Trip to the site.

Primary children can do a superficial investigation, guided by the teacher, who can be guided by some of the questions below. Older students can be more thorough in their search, as well as more persevering and inventive in thinking up their own questions.

Problems:

What is the size of brittle stars compared to your hand?

What color are they?

How many arms do they have?

In what kinds of places do you find brittle stars? free swimming in the water? hiding in crevices or under rocks? buried in the sand? resting on the bottom? up on the dry beach?

Do brittle stars seem to live alone or several together?

What plants and other animals live near the brittle stars?

Do brittle stars move fast or slow? How do they use their arms in moving?

Pick up a brittle star and hold it gently in your palm. (They are not poisonous and do not bite.) Can you keep it in your hand? What does it do? Do not be surprised if it drops off one or more of its arms in an attempt to get away from you. New arms will grow back gradually.

Do any brittle stars which you find show evidence of having lost an arm or of growing back a new one?

Suggested Procedures.

On the field trip, the students might be divided into groups to search different parts of the shoreline waters for brittle stars. If the tide is low it should not be necessary to go beyond ankle depth to find them in crevices and under rocks.

Students often do not "see" the things they look at until various points of observation are brought to attention in discussion. This can best be done sitting on the beach after a preliminary survey of the area. The students will have their own observations and questions to contribute. The problem questions above can be selected from and adapted by the teacher to keep comments going.

After the teacher and students have mentioned noticing various items about brittle stars and generated further questions, the group usually needs to return for a second look, this time more alert to points to observe.

Problem 2. OBSERVATIONS ON CAPTIVE BRITTLE STARS BANDS 1, 2, 3

Bring a few brittle stars of different sizes from the reef to the classroom aquarium in a covered bucket having a battery pump. Plan to return them to the sea when the observations are complete.

Primary students will enjoy simply watching the graceful movements of brittle stars. Older students can sketch them, do feeding and behavior investigations, and make notebook reports.

Materials.

- *-Covered bucket with battery pump for bringing specimens to the classroom tank*
- *-Classroom aquarium*
- *-Several glass pie plates (or the equivalent) for close-up, small group observation*
- *-Extra sea water*

Problems:

Place a brittle star in a glass pie plate with sea water. Make a careful sketch of it in color. Draw a general view of the shape; then draw a close-up view of the central disk and the underside of one arm.

How can you measure brittle stars for size? by length of one arm? by diameter of the central disk? by diameter from tip to tip of extended arms? by diameter when lying coiled up and quiet?

Using whichever standard of measurement you decide upon, what is the size of your brittle stars? Have you ever seen larger or smaller ones?

What is the size and shape of the central disk?

Look through the glass from the bottom and see how a brittle star moves. When it travels, does it always put the same arm first or does it go in any direction using any arm? How could you mark the arms so you will know which is which?

Turn the animal upside down. How does it go about turning itself over? If you turn it upside down repeatedly, does it always right itself in the same way? Does it always use the same arm or arms to turn over?

Are the arms brittle? Can they move in only horizontal directions? Can they move in any direction like an octopus arm? Can they grasp things with the tip?

(cont'd on next page)

Problems: (cont'd)

Feed the brittle star a tiny bit of fish or other scrap and carefully watch the movement of the arms in transferring the food to the mouth and of the mouth in eating.

A star fish uses its tube feet like small suction disks to cling to rocks and shells. A brittle star also has tube feet but they do not act as suction disks. What does a brittle star's tube feet seem to be used for?

When you are finished sketching and observing your brittle star, put it in the class aquarium. Drop it into the water and see if it swims or does it just drop like a dead weight to the bottom of the tank?

Can a brittle star climb up the vertical walls of a glass tank?

Do brittle stars move more frequently toward the light or into dark parts of the tank? How could you do a test on this to find out?

What different kinds of food will your brittle star eat? What does it like best?

Keep a general watch on your brittle star in the class tank from day to day and week to week. How does it get along with other brittle stars? How does it behave toward other animals in the tank? How do the other animals treat it?

What other investigations would you like to make with your brittle star?

Suggested Procedures.

Group a few students around each glass dish containing one or two brittle stars. Put enough clean sea water in each dish to completely cover the animals.

You might write some of the problem questions on the board as a guide for the students, or you might ask them to observe anything they can while you go around and make comments and ask questions of each group. In a general discussion, some or all of the points made in the problem questions can be brought out.

The word brittle in the name brittle star has nothing to do with stiffness. Brittle star arms are flexible and agile. The tube feet are sensory organs.

Brittle stars should not remain in the glass dishes over night. Return them at the end of the observation period to the class tank. There, further investigations can be made concerning their eating habits and their activities in relation to other animals. When dropped into the tank, a brittle star often plummets to the bottom. The animals can swim, however, and do so quite gracefully and rapidly.

If crabs are part of the class tank community, you can expect at least one of the brittle stars to lose an arm or two. Theoretically, the arm stump regenerates a new arm, and it will do so if the brittle star is fed and cared for in isolation. Left in the tank, an injured animal becomes fair game for further attack and is soon completely devoured. This is an opportunity for a lesson on the balance of nature and the food chain of the sea.

For long term observation, keep the brittle star population down to two or three per tank, unless you have a tank which contains nothing but brittle stars.

Older elementary students can be expected to write a report in their notebooks about their brittle star investigations. See the PROGRAM MANUAL for styles and procedures on reporting.

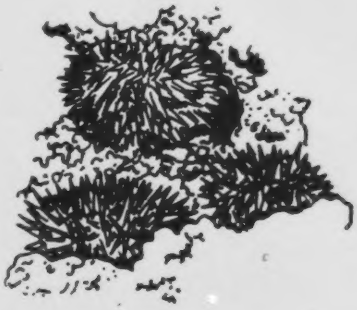
Depending on class interest, you may wish to encourage brittle star art, poetry, music, or story telling.

SEA URCHINS

Introduction.

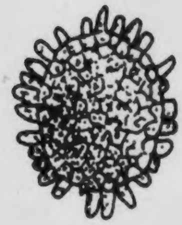
Sea urchins are members of Phylum Echinodermata, Class Echinoidea. Sea urchins reflect their membership in the phylum by the presence of tube feet, and by a radial symmetry which is more noticeable on the denuded skeleton.

Several genera of sea urchins are commonly seen in Hawaiian waters. Two common tide pool species, Echinometra spp., called 'ina in Hawaiian, are black or light greenish in color. These abundant urchins use their spines and rasping mouth parts to dig holes in the reef, widening and deepening the cavity as they themselves grow larger. Eventually they become imprisoned (or well protected?) in small-mouthed holes from which they can no longer get out, nor be pulled out.



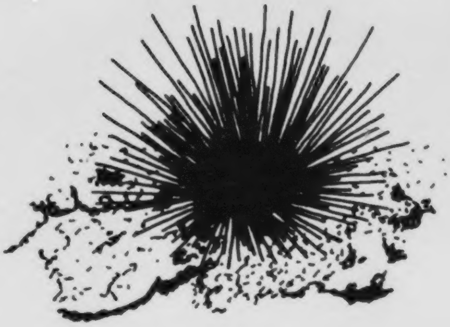
ECHINOMETRA SPP.

A common urchin, Colobocentrotus, is shingled with blunt, flat, dull black spines and clings to surfaces of rocks in the intertidal zone where waves pound.



COLOBOCENTROTUS

In deeper water are found the large wana which are a Hawaiian delicacy eaten raw. Wana are jet black with long, needle-like spines. The spines are poisonous and easily penetrate the skin when touched. The common wana is Echinothrix sp. Diadema sp. are found off the Big Island, The students will not likely encounter these except possibly young specimens which may be in shallow water.



ECHINOTHRIX SP.

Tripneustes sp. is a large bodied urchin with numerous very short black spines, also found in deeper water. This urchin has the habit of camouflaging itself with a cover of pebbles and sand grains which it moves onto itself.

A tide pool visit gives opportunity to view shallow water urchins in their normal habitat and study their general ecology. For further close observation, a few urchins may be brought back to the class tank or kept briefly in aerated gallon jars. Upon completion of the student investigations, the urchins should be returned to the sea.

Problem 3. FIELD OBSERVATIONS BANDS 2, 3

During an Extended Field Trip to a tide pool area, sea urchin observation and discussion may occupy 15 to 30 minutes of the day's agenda, depending on urchin variety and abundance, and on student interest and ability. See Section I on Extended Field Trip planning and procedures.

Problems:

Look for sea urchins in tidal pools and on rocks at the wave break line.

What different sizes and colors of urchins can you find?

Look for flat, black urchins on a rock face in the splash zone.

Can you get a tide pool urchin out of its rock hole without hurting or breaking it?

What other animals live with or near the urchins?

Look under the urchin for tiny mollusks and worms which live on the urchin near its mouth.

What do you think sea urchins eat?

Keep an eye out for sea urchin tests (skeletons).

Suggested Procedures.

Prepare students for field observations of sea urchins by going over some or all the Problem questions above. Pictures or sketches of urchins and an urchin test (skeleton) might be shown to them so that they will know what they are to look for but without revealing answers to the observation questions. An alternative is to wait until the class is gathered at the beach. Then show them an urchin, while at the same time suggesting some observations they might make, using the above questions as a general guide.

The question on sizes might be answered in the field with a guess in centimeters or inches or by comparison with something of familiar size such as a hen's egg or one's own thumb. Specific measurement in inches or cm can wait for close-up view in the laboratory.

Getting a sea urchin out of its hole in the coral is next to impossible without breaking either the urchin or the rock. The trick is to dislodge the urchin before it clamps down tightly in response to being disturbed. Student guesses as to what sea urchins might eat can be based on where they live, what lives around them, and observations of what kind of teeth or mouth structures they have.

Problem 4. CLASSROOM OBSERVATIONS OF SEA URCHINS BANDS 1, 2, 3

This problem can come after the field observations have been made, or it may serve as an introduction to sea urchins for students who were too young or had no opportunity to observe urchins in the field.

Materials.

- *Bucket or jar with a battery pump for bringing urchins from the reef to the class tank*
- *Large glass jars with sea water for groups of student observers*
- *Several flat pans with sea water for further student observation*

Problems:

What sizes are sea urchins? In trying to determine the size of a sea urchin, what should you measure? its height, diameter, length of spines? diameter of body without spines?

What different kinds of body parts does a sea urchin have? Look for tube feet. How long are the tube feet compared to the spines? Are all the spines alike or do they differ in lengths and other characteristics? Can the spines move?

How do sea urchins move? Watch an urchin climb the glass wall of the aquarium or of a glass jar. Observe the movements of the tube feet through the glass.

Does an urchin have tube feet all over its body or only on the crawling surface? Carefully place an urchin on your hand. Are the tube feet soft? sticky? too weak to feel? Do the spines prick?

How fast, in inches or centimeters per minute, can a sea urchin move? Can you change the light or food supply or other circumstances to make it move faster?

Turn an urchin upside down. Can he right himself?

Place a small stone or other object on top of the spines. What does the urchin do about it, if anything?

How does an urchin eat? Examine the mouth. Can you see five teeth? The five teeth and the hard-walled structure behind them have a shape like an old Greek lantern. The teeth and five boney structures are called Aristotle's lantern. (Who was Aristotle?)

What does a sea urchin eat? Predict what you think you should feed your urchins. Might they eat some of the things already in the class tank? What kinds of foods do their mouths, teeth, and movements seem to indicate they might be able to handle?

Suggested Procedures.

Questions and comments adapted from the problem questions above may be helpful in stimulating the students in case they fall by the wayside in pursuing investigations on sea urchins on their own initiative.

In a battery-aerated bucket or jar, bring back from the reef sufficient urchins for each group of student observers to have at least one in a glass jar. The sides of a glass jar allow observation of the mouth area and tube feet and spine action while crawling.

Each group of students also needs a shallow pan of sea water for observing some of the other sea urchin behaviors.

For size measurement, almost any standard the students decide upon is useable provided they all measure the same way. For example, they may all agree to measure diameter from spine tip to spine tip looking down from above, or they may decide to compare urchins by measuring their heights, or the size of the body proper, not counting spines.

Regarding body parts, the students should note the mouth and teeth, the spines which are movable in a "ball and socket" type joint in the skeleton, and the soft, suction disk tube feet. A plumbers helper or other suction devices could be used to demonstrate how the tube feet keep the urchin sticking to the sides of the glass wall.

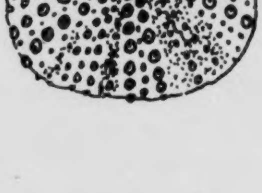
When stones, bits of aluminum foil, and other objects are placed on top of an urchin, the spines usually move to negotiate the object off the urchin, except in the case of one species (Tripneustes) a deep sea, short-spined urchin which purposely picks up small stone and puts them on top of itself as a camouflage.

The students might try a variety of foods to see if they can detect food choices. Predominantly, urchins are algae eaters, particularly of rock-encrusting algae which they rasp off with their teeth. Rasping may be observed on the encrusted algae on the sides of the aquarium glass.

During the few days or week that the students are observing their urchins in gallon glass jars or flat pans, change the sea water every two or three days, unless clouding of the water from overfeeding indicates a more frequent change. After about a week, one or two urchins can be retained for the class tank and the rest be returned to the sea.

Problem 5. THE SEA URCHIN TEST (SKELETON) BANDS 1, 2, 3

The students may have found a whole or a piece of sea urchin test on the beach. People often keep urchin tests as ornaments in their houses. Perhaps one or more of these could be borrowed for class observation.



Problems:

What is a sea urchin test? What does it seem to be made of?

Notice kinds and numbers of bumps on the test. Notice the pattern of the bumps.

What might be the cause of the bumps on the test?

What might the holes at the top and bottom of the test be for?

What might be the use of a test to a sea urchin?

What art or craft object could you make with a sea urchin test?

Suggested Procedures.

Students may be able to surmise for themselves that the sea urchin test is the urchin's skeleton which protects the soft body parts and provides anchorage for the spines. The bumps on the test are the sockets in which the spines are set. Be sure the students notice that the rows of bumps up the sides of the test from mouth to center top are five in number. This is the sea urchin's claim to membership in the star fish phylum.

The hole in the bottom of the test is for the mouth. The hole in the top is the anal opening. Water is also transported through the test wall via tiny sieve holes.

Regarding what a test is made of, if the students have already studied sea shells they will know the vinegar test for calcium carbonate and can apply it to a piece of test with positive results.

Sea urchin tests are crafted into ornaments of all sorts. The students' creative imaginations might give origin to any number of beautiful or interesting artifacts.

Other Sea Urchin Possibilities.

Growth of sea urchins is probably too slow to hold the interest of young children, but for any who are interested, data might be kept on increase in diameter from week to week or month to month.

At spawning time, male urchins spew out clouds of white semen while the female releases clouds of yellow eggs into the water. The phenomenon might by chance be observed.

Conclusion to Sea Urchin Investigations.

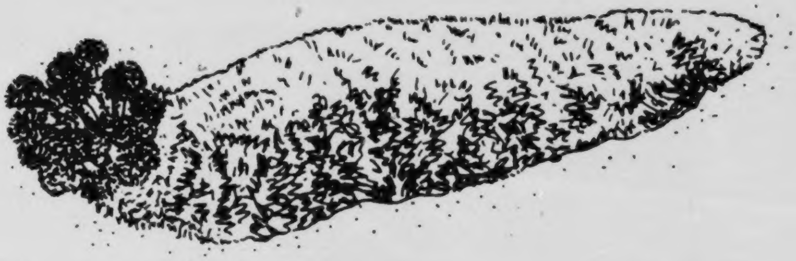
Student notebooks should reflect what they have been studying about sea urchins: observations, experiments, data, diagrams, conclusions, poetry, stories, art work, etc. See the PROGRAM MANUAL on student reporting techniques.

SEA CUCUMBERS

Introduction.

Sea cucumbers are members of Phylum Echinodermata, Class Holothuroidea. Hawaii has many genera and species of holothurians. Those around most of our shorelines are tough-skinned, range in size from two inches to two feet, and in color from black to brown to reddish to pale. One spectacular species in Kaneohe Bay is thin-skinned, light colored, and long. When it is lifted out of the water, the skin stretches out lengthwise. The inner organs flow down into the dangling portions of the body while the part held in the hand collapses into what resembles an empty section of limp intestine.

SEA
CUCUMBER



The sea cucumber's claim to membership among the echinoderms rests chiefly with its five rows of reduced tube feet which run the length of the body from mouth to anus. Sea cucumbers live in and on sandy bottoms, sometimes sheltered under rock overhangs. They are filter feeders, taking in sand and detritus with the help of their oral tentacles as they tunnel through the sand. Sand pellets are extruded from the anus.

Respiratory trees, which are much convoluted tubules are located just inside the anal canal. The rhythmic pulsating of the anus pumps water, from which oxygen is extracted, in and out of the respiratory trees. The speed of the pulse is related to the temperature of the water.

As a defense or under stress, the sea cucumber expells (eviscerates) its complete set of respiratory trees and some other internal organs, spewing them out like long thin skeins of spaghetti. The cucumber soon regenerates a new set of inner organs.

A tiny black and white crab, Lissocarcinus sp., lives inside the mouth cavity of the sea cucumber as its natural habitat.

The Chinese were the first to gather and dry sea cucumbers which are sold as "trepang" or "beche de mer" for making a highly prized gourmet soup.

Investigation with Sea Cucumbers.

Problem 6. FIELD OBSERVATIONS ON SEA CUCUMBERS BANDS 1, 2, 3

Sea cucumbers are best examined in the field, then left there. Sea cucumbers are most easily found at low tide curled into a crevice in the reef, looking like part of a dark rock lightly covered with a thin layer of sand.

Materials.

- *A small bottle (pill bottle size) containing some household ammonia. At the beach, a small amount of ammonia added to a bucket of sea water approximates a 0.1% solution of ammonium hydroxide which is a stimulant for sea cucumber evisceration.*

Problems:

Look for sea cucumbers on the reef.

Where do you find them? Are they more often on bare rocks? among sea weeds? in the sand? on top of the sand? in the mud?

What color are they? Sometimes they have a layer of sand sticking to them. Does your specimen have sand on it? Why might the layer of sand be there? Is it an accident or does it serve a purpose?

What different sizes of sea cucumbers can you find? What is the largest and smallest?

Pick up a sea cucumber. They are not poisonous and will not bite you.

Squeeze it gently. What comes out?

Look at your hands after you have handled a black sea cucumber. From the skin of some black sea cucumbers a red dye rubs off onto your skin. It is not harmful.

(cont'd on next page)

Problems: (cont'd)

Put your finger into the mouth of a sea cucumber. You may find a little black and white crab in there. Take it out and examine it. This little crab lives in sea cucumber mouths.

Put a sea cucumber into a bucket of sea water. If the animal becomes too warm or uncomfortable, it may eviscerate. "Eviscerate" means to spew out the viscera or inner organs. This is how a sea cucumber frightens its enemies. Afterwards, it grows a new set of inner organs. If your sea cucumber is reluctant to eviscerate, you can induce it by adding a very small amount of household ammonia into the bucket of sea water. Examine the viscera which have been spewed out. Feel the stickiness.

Examine the sides of a sea cucumber body. It has five rows of small tube feet. Find them. The rows are usually not the same distances apart, nor all of the same size. How are they arranged?

Look for the mouth tentacles. They may be withdrawn, or they may be stretched out. What do you think they are for? What do you think a sea cucumber eats?

Suggested Procedures.

The students may have some difficulty finding their first sea cucumber because of the good camouflage of sand covering their bodies. It usually causes some student excitement to find how big some of the specimens can grow. Some very small sea cucumbers may also be found.

When the students hold up a sea cucumber and gently squeeze, what usually comes out is a stream of water. From this you might help the students conclude that the cucumber is not solid "meat" but contains much sea water.

It is possible that a sea cucumber may eviscerate with no more provocation than being squeezed in a students' hands. In that case the student is in for a surprise as he tries to free himself from the sticky mess. It is only uncomfortable, not harmful.

Most sea cucumbers at low tide lie at rest with tentacles withdrawn. With luck, you may find one actively feeding, in which case call student attention to the oral tentacles and the undulating motions as the animal works its way through the sand.

It may be necessary to teach some sea cucumber vocabulary. This can be done during the student observations as need for using the terms arises. Definitions are given here in one list for teacher convenience.

Vocabulary.

ORAL: at or toward the mouth end of an animal

ANAL: at or toward the anus or defecating end of an animal

VISCERA: the internal body organs of an animal

EVISCERATE: spewing out of viscera done by sea cucumbers

PERISTALSIS, or PERISTALTIC ACTION: a wavy series of contractions and expansions which pass along a tubular organ such as an intestine. Peristalsis moves food through an intestinal tract, including the human intestinal tract.

RESPIRATORY TREES: much branched tubules in sea cucumbers connected to the anal canal which extract oxygen from sea water as the water is moved in and out.

Problem 7. LABORATORY INVESTIGATIONS ON SEA CUCUMBERS BAND 3

This problem is recommended only for teachers and students who have sufficient devotion to sea cucumbers to be willing to clean up the mess and contamination they usually produce. Keep them out of the class aquarium and maintain them in their own tank. Then at least only one tank will become fouled. Also, work with small specimens.

One pilot teacher, using exceptionally young sea cucumbers, was able to maintain them successfully for weeks in a large and seasoned class aquarium. However this is not the general experience or good luck.

This activity assumes that observations on sea cucumber general appearance and behavior has already been done at the beach.

Materials.

- *A pan or other container with sea water, an air stone, and a shallow sand bed (sand of about same depth as diameter of animal)*
- *Watch or clock with second hand (if pulse counts are to be taken)*
- *Hand lens*
- *A means of maintinaing water at different temperatures (if the investigation on temperature differences is pursued)*
- *Other equipment which BAND 3 students may need for their own inventions*

Problems:

How does a sea cucumber burrow through sand? How does it move its body forward?

(cont'd on next page)

Problems: (cont'd)

How do the tentacles around the mouth move? What are they doing? How many tentacles or rows of tentacles can you count?

What comes out of the sea cucumber at the anal end? You will notice that much of it is sand. How did all that sand get into the sea cucumber? Why do you think a sea cucumber would take in so much sand?

With a hand lens, examine the five rows of tube feet along the length of the body. How do they compare with the tube feet of sea urchins and brittle stars?

When a sea cucumber is lying still, notice any pulsing movements at the anal end of the animal. These movements are causing water to move in and out of the respiratory trees. What might the respiratory trees do with a constant change of sea water?

Count how many respiratory pulses per minute. Change the temperature of the water. Let the sea cucumber adjust to the new temperature for about five minutes. Then count the number of respiratory pulses per minute at the new temperature. Try several different temperatures. What can you conclude about the effect of temperature on the rate of respiration?

What other investigations would you like to make on your sea cucumber?

Suggested Procedures.

Sea cucumber movements are not easy to observe because most of the time the animals lie still in the sand. However after a day or two the students may notice burrowing tracks and pellets of sand which have been expelled from the anus. The sand is gathered in by the mouth tentacles and passed through the digestive tract by peristaltic action. On the way through, fungi, bacteria, and other tidbits of nourishment are extracted from the sand. The grains are expelled from the anus held together by a mucus. Sea cucumbers are called filter feeders.

The respiratory pulsation moves aerated water through the respiratory trees where oxygen is extracted. The respiratory pulse quickens with a rise in temperature and slows with a cooling of the water. Give the animals ample time to adjust to the new water temperature before taking the respiratory pulse count.

After observations are complete, return the sea cucumbers to their natural habitat.

Problem 8. THE ECHINODERMS

BANDS 2, 3

After the students have observed two or all three of the members of the echinoderms given here, namely, brittle stars, sea urchins, and sea cucumbers, they should be able to draw a conclusion about characteristics they have in common.

Problems:

Look at your sketches and notes about brittle stars, sea urchins, and sea cucumbers. What body structures or characteristics do all of them have in common?

These three animals, along with others from deeper in the sea, are called echinoderms which means "spiney skinned". Is this a good name? Can you think of some other names which would describe this group of animals?

Suggested Procedures.

Assist the students to note that all the members of this group have tube feet which, in one pattern or another, are arranged in rows of five. The spiney skin is not so obvious in sea cucumbers although this also is a group characteristic.

Students may prefer a name like "five pointers" or some such as their invention.

FROM SHELLS TO A STUTTER (A puzzle for older elementary students)

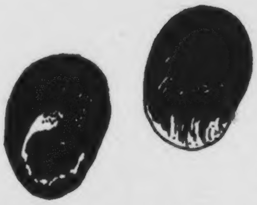
1.	C O W R I E S	Start with a bunch of cowries.
2.	___ ___ ___ ___ ___ ___	Take out the "i" and rearrange the remaining letters into a deed or bond held in security.
3.	___ ___ ___ ___ ___	Out with the "w" and get the points earned during an athletic game.
4.	___ ___ ___ ___	Remove the "s" and get into the very middle of things.
5.	___ ___ ___	Subtract the "c" and find some fish eggs.
6.	___ ___	Let go of the "o" and you are left with a stutter.

(Answer: cowries escrow, score, core, roe, er.)

6. NERITES AND PERIWINKLES

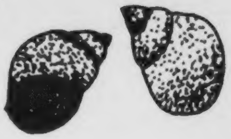
Introduction.

Our common Hawaiian black, rounded nerites (pipipis) and grey, pointed periwinkles are marine mollusks of the sea snail class (Gastropoda). Because they are air breathers, these two snails can live above the water line on rocks where they are both abundant and easily accessible.



NERITES

Later, the students will have opportunity to look at many beautiful deep water shells which are not seen in the living state at the shoreline. Nerites and periwinkles offer opportunity to study sea shells which are still in the possession of the snail animals that make them.



PERIWINKLES

In collecting snails for classroom work it should be brought to the children's attention that if every class in every school collected dozens of snails and failed to return them to the rocks afterwards, we could wipe out the species despite their abundance along our shorelines at the present time.

Sea Snail Investigations.

Problem 1. FIELD OBSERVATIONS BANDS 1, 2, 3

Periwinkles and nerites are best studied at the beach where the students can observe their clustering and note the zonation. Periwinkles usually live high on the dry rocks; nerites are below closer to the water line.

The following multitudinous questions are not for reading or giving verbatim to students. They are suggestions for teachers to keep in mind and use as feasible during the time at the beach.

Problems:

*What colors and shapes are nerites and periwinkles?

*What size is a nerite and a periwinkle compared to your finger tip or some other familiar object. How long are they? How wide? What sizes are the biggest and the smallest ones you can find?

(cont'd on next page)

Problems: (cont'd)

What kind of rocks do the nerites and periwinkles live on? rough? smooth? both rough and smooth? dry? wet? both?

Where on the rocks do the nerites and periwinkles live? near the water? high up? in the cracks? on open flat surfaces?

How tightly do they cling to the rock? Is it hard to pick them off?

Do nerites and periwinkles live mixed together or does each kind of snail keep with its own kind?

*Do nerites bunch together or does each snail go its own way?

*Do periwinkles crowd together or does each one keep to itself?

Can you find nerites and periwinkles in the sand? on the coral? in the tide pools?

*Do sea snails move or do they always stay in the same spot? Did you see any of them move?

Pick a nerite or a periwinkle off the rock and quickly look at its foot. (Its foot is the rubbery-looking part on which it rests.)

Place the nerite or periwinkle upside down in a very small pool of sea water and watch its foot come out of the shell. Watch for a few minutes to see what the snail does.

What else, if anything, lives where the nerites and periwinkles live? Any sea weed? Any other rock-dwelling animals?

*What do you think sea snails eat? What do their relatives, the land snails (garden slugs), eat?

*Indicates questions which can be used in Problem 2 also.

Suggested Procedures.

1. Set up a field trip, either a short trip for the sole purpose of observing sea snails on shoreline rocks, or make sea snail observations a half hour or an hour portion of an Extended Field Trip. See Section I on Extended Field Trips for ideas on management and arrangements.

   Aim for a low or an outgoing tide for safety's sake, even though nerites and periwinkles live above the water line.

2. Before going on the field trip, show the students a quick rough sketch or picture of nerites and periwinkles so that they will know what they are looking for, but do not describe details. That will be their job to observe.

3. From the numerous questions in Problem 1, give a few questions to the students ahead of time to give them something to start looking for. The remainder of the questions in Problem 1 can reside in the teacher's head or pocket. Later in the field while the observations are in progress, drop additional questions informally here and there to match observational opportunities. Questions can be curtailed or expanded to match the patience, interest span, and ability of the class.

4. BAND 1 students complete their work for the day when they have observed, remarked, exclaimed, and are about to grow tired.

   BANDS 2 and 3 students can be expected to do some notebook reporting with sketches. See the PROGRAM MANUAL for reporting format.

Problem 2. CLASSROOM OBSERVATIONS — BANDS 1, 2, 3

This problem presupposes the setting up of a gallon jar with a transparent plastic "chimney" as shown in the diagram.

The eight questions in Problem 1 marked with an * belong here in Problem 2 if they were not done in Problem 1. The questions below are additions.

Problems:

Place a few nerites and periwinkles within the plastic circle at the bottom of the gallon jar. What do they do? Where do they go?

Do all the snails move together in one bunch or do they travel one by one? Watch for any "follow the leader" behavior. Do many snails follow the leader, or only a few, or none?

How high up the plastic column do they go? Do they all stop at the same height? Is there a difference in heights sought by nerites as compared with periwinkles?

After they stop crawling, are they bunched together, or do they come to rest in separate spots?

Watch the movement of the foot through the transparent plastic. How does a sea snail move on its foot?

(cont'd on next page)

Problems: (cont'd)

How does a sea snail stick to the plastic? Feel the track left behind as it crawls. Pick a snail off the plastic to see how tightly or loosely it holds on.

Pick a snail off the plastic and watch the movement of its foot as you hold it in the air. Then place it upside down in a shallow pan of sea water and watch what its foot does.

Does a sea snail crawl faster, or slower, or differently, in water than it does on dry plastic?

Using non-water-soluble ink or paint, mark the snail shells so that you can later identify individual shells. Make dots on a map showing where each snail is located each day.

How fast does a sea snail move up the side of a transparent plastic cylinder? Use a watch and a ruler to measure the speed in inches or centimeters per minute.

Do you agree with the expression "slow as a snail"? Try the following arithmetic problem on snail speed and see what you think. You are about 100 times bigger than a nerite or periwinkle (assuming a student is 50 or 60 inches tall and a snail is ½ inch or 3/8 inch long). Multiply the distance which a snail moved in one minute times 100. This is how far the snail might move in one minute if the snail were your size. How does this speed compare with your human speed?

What are you going to do with your sea snails when you have finished observing them?

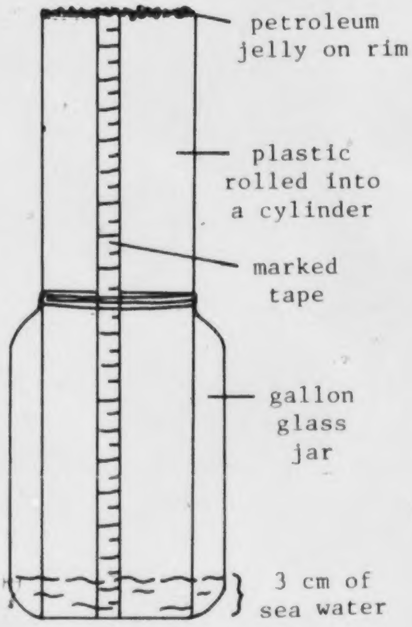
Suggested Procedures.

Set up a gallon jar sea snail tank as follows:

Roll up a rectange of stiff, transparent plastic to form a tall cylinder, at least three feet high.

Make the diameter of the "chimney" to fit snuggly through the neck of a large-mouthed, glass gallon jar.

Use a strip of masking tape to close the cylinder. Mark this tape in inches or centimeters to serve as a measure on the side of the cylinder.



Set the cylinder into the jar flush against the bottom, so that sea snails must remain inside the cylinder.

Put about an inch of sea water into the jar. No aeration or air stone is needed.

Smear petroleum jelly or an equivalent around the top edge of the plastic cylinder to prevent snails from crawling out over the top. An alternative is to cover the top of the cylinder with a piece of nylon stocking held taut by a rubber band.

If the class is large, set up several such cylinders and jars so that all the students can observe comfortably and simultaneously.

At the beginning of the class observation period, place about a dozen each of nerites and periwinkles in the gallon jar inside the circle made by the plastic column.

Most of the observations in Problem 2 center around snail movement which is easy to follow when the snails are first placed in the plastic cylinder. They glide slowly over the surface on their foot, leaving behind a slime trail. One snail often follows in the trail left by a previous snail. After they settle, movement becomes less perceptible unless the paint marking system is used.

Movements up and down in the cylincer can be correlated with the rise and fall of the tide. A number of animals who occupy the intertidal areas display a circadian rhythm in response to the tides, even when removed from tidal areas. A few pilot teachers have had success in graphing daily up and down movements of snails and comparing these with highs and lows on the tide chart.

Eating can be observed with a hand lens aided and abetted by considerable luck and patience. Immerse a pane of glass or heavy plastic in the class aquarium until it builds up a surface scum of algae. Place some snails on the pane and see if rasping movements of the mouth can be observed through the glass.

These air breathing snails can remain immovably attached to rocks or to the plastic cylinder (or classroom wall) for weeks and even months without apparent harm. When taken down and placed in sea water they revive immediately.

Observations of nerities and periwinkles by BAND 1 children will, of course, be less sophisticated and detailed than the written and illustrated notebook reports which can be expected from upper elementary students.

7. SEA SHELLS

Introduction.

People of all ages are attracted to the beauty of color and form found in myriad species and varieties of sea shells. Serious collectors number their shells in the hundreds and thousands and their value in comparable amounts.

It comes as a surprise to some people that sea shells are the product of living animals. The preceding topic, Nerites and Periwinkles, focused attention on the living animals which make two of our common shoreline shells. Investigations in this topic are designed to acquaint students with the spectacular beauty and variety of shells. Problem 7 for older students gets into species variation and the consideration of normal distribution patterns. The problems involving craft work using shells might prove to be of artistic interest to all age groups with varied results depending upon their skills and degrees of dexterity.

Collecting living shells in offshore and deep water is beyond the capability of nearly all elementary children. Even if they could collect them, it would not be adviseable from the point of view of conservation. A review of "The Shellers Creed" quoted in Section 1 of this book under the heading "Conservation" is appropriate at this time. Sufficient shells are usually available from home collections, from shops, and in picture form so that students can experience the richness of holding, feeling, seeing the beauty, and arriving at some understanding of sea shells.

Investigations with Sea Shells.

Problem 1. THE VARIETY OF SHELLS — BANDS 1, 2, 3

In this problem we are not concerned with sorting shells by family, genus, or species, nor about names for shells. That will come later. Here the thrust is simply to become aware of shells in their many kinds, sizes, shapes, colors, and convolutions.

Problems:

What kinds of sea shells can you find samples of, or pictures of?

What colors, shapes, structures, and sizes do shells have?

Suggested Procedures.

1. As a preparation for this class, assemble a few real shells and a few pictures of shells. Show these to the class and ask the students if they know where they can find other shells.

2. Designate a "shell day" on which shells and pictures of shells can be brought to school to be looked at and admired. For very young children, this is invariably the very next day.

3. The next step in the activity will depend largely on the quantity and quality of shells and pictures which are brought in.

    a. The response may be minimal. Hardly anyone seems to have shells to share. Pictures may need to be relied upon. Library books may be borrowed having colored plates which can be shown on a screen using the opaque projector.

    b. The response may be "midling." A few students may bring in some beach worn shells or perhaps some shell leis. Others may have found pictures. Whatever specimens arrive can be displayed, passed around, admired, commented upon, examined.

    c. The response may be great. Someone's aunty is a sheller who has a collection to share with the class, perhaps even come herself to show and talk about the shells. Someone's big brother has a helmet he is willing to lend for a day. Costume shell jewelry and souvenirs from living room shelves at home may be brought in to be duly admired. Students may come forth with quite a variety of beach pick-ups. A "Show and Tell" on shells may be feasible.

4. Work with whatever shells and pictures have been brought in to help the students to become aware of shell sizes, shapes, colors, and designs. The following questions and directions translated to the language level of the class may be used as desired to enhance observations.

    -Hold a shell in your fingers or cup it in your hand. Feel it. Rub it gently. Is it smooth? Rough? Ridged? Grooved?

    -What color is your shell? Is it white and beach worn? Does it still have some of its original color? Does it have spots, stripes, blotches of color? Are the colors sharply defined or do they blend one into another?

    -What shape is your shell? Is it round? Does it have sharp edges and points?

    -If it is a large shell, hold the opening to your ear and listen. Can you hear anything? (Poetically you hear the ocean. Actually, you hear echoes of small sounds amplified in the shell's inner labyrinths.)

    -Look at the edges of the opening. Do you see folds or ridges? In some species of shells these are called teeth but of course they are not for chewing. In miter shells these folds are prominent and characteristic of the family. How many ridges does your shell have? Are they colored?

-What color is the inside of the shell as far in as you can see?

-Is your shell a one-piece shell, or a two-piece shell? If it is a two-piece shell, can you see the hinge area where the two pieces are grooved together?

-Do you have any broken shells? Can you see any broken spiral sections which were once inside a shell?

5. Since this problem is simply an awareness lesson, the exercise comes to an end without the usual written report.

Problem 2. REPLICATIONS OF SPECIAL SHELLS BANDS 2, 3

Here, the students use pliable dough or paper to mold shells to duplicate those in their collection. This work of replicating shells serves several functions:

1. Students pay more attention to, and become more aware of, shapes and textures when they are engaged in reproducing objects. Attention needed to copy the shell heightens and gives focus to observation.

2. As the students work at molding their paper or dough shells, they become handicapped by not knowing what to call "this bump," "that sharp corner," "the place in here." This leads to questions about what to call things and gives vocabulary learning a functional purpose. A glossary of common terms for shell structures is in the next problem and can be brought forward at this time in response to questions being asked.

3. There may not be enough shells in the collection from Problem 1 for every student group to have one of each kind. If shells noteworthy for their size, shape, or rarity are reproduced, each student group can have at least one copy of each special shell to use later in Problem 4 on sorting.

4. Shells can get scratched or chipped in the shuffle of the student sorting process. Uncle Tony will not appreciate having his very best shell returned to him with two spines chipped off. Such special shells can be put safely on a shelf for viewing only, while copies of them are used by the students for handling and sorting.

Problem:

Make copies of your best, biggest, or rarest shells.

Suggested Procedures.

Select from the shells available those which offer the best or most interesting shapes for reproduction, as well as those which need to be reproduced so that there will be enough for the sorting process in Problem 4.

Divide these selected shells among the students with the challenge to make copies of them by any means they can. The reproduction should be exact enough so that it can be used in place of the shell for identification purposes later. This demand for exactness increases observation of detail.

The following ideas for making reproductions may be chosen from, or other ideas may be invented by teacher or students.

Method #1. Take colored snapshots of the shell. Photograph from the top, side, bottom, and any angles necessary to show special features. Mount the pictures on a cardboard. Measure the shell and indicate the actual size by scale lines drawn on the cardboard.

Method #2. Use clay or make some modeling materials to sculpt a replication of the shell. The following are three possible dough recipes:

1. FLOUR CLAY

   1 c flour
   1 c salt
   1 rounded tsp powdered Alum

   Add water slowly and knead until a claylike consistency is reached. Store wrapped in wet cloth and plastic.

2. "PEOPLE DOUGH" (M. Pappas)

   4 c flour
   1 c salt
   1½ c warm water

   Mix flour and salt thoroughly. Add water and mix well. Knead dough at least 5-10 minutes. Keep unused dough covered with plastic wrap to prevent crust formation. Dough cannot be stored. Bake 20-60 minutes depending on size of forms. Dough is done when it is completely hard.

3. BREAD AND GLUE

   Fresh white bread
   Elmer's or white glue

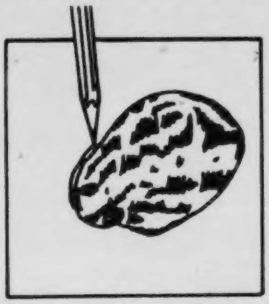
   Mix sufficient white glue with crumbs of fresh white bread to form a dough. Use this dough for modeling. Let dry to hardness.

All three of the above recipes use ingredients which are water soluble. For that reason, the finished models may absorb moisture from the atmosphere on humid days. As soon as the shell models are dry, spray with a water-proof coating or coat with nail polish before coloring. Have the students try to reproduce the delicate shadings of the real shell in their models using water color or other paints.

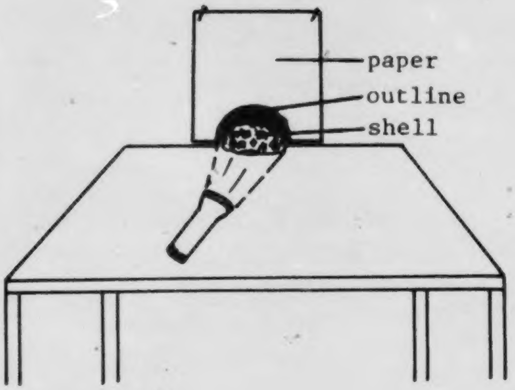
Method #3. Make a papier mache reproduction of a shell.

Method #4. Make a three-dimensional cardboard shell as follows:

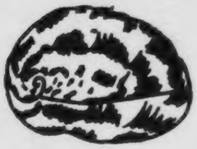
1. Place the shell on a piece of stiff paper. Trace around it to obtain an outline of the shape as seen from above. Cut out and color with crayons or colored pencils. Turn the paper over and color the underside to match the underside of the shell.



2. Place the shell on a table up against a wall. Pin a piece of stiff paper on the wall. Shine a light to make a shadow of the shell on the paper. Hold the light at the same level as the shell so that the shadow will be the size and shape of the shell as seen from the side. Trace around the edge of the shadow. Cut out and color.



3. Anchor the side view to the center of the base piece by using glue, tape, or perhaps by means of a flap extension allowed at the bottom of the side view piece.



Method #5. Invent any other way to make a copy of a shell, such as by carving from styrofoam or balsawood, by making detailed sketches from several viewpoints, by making rubber molds and pouring in plaster, or by whatever techniques fall within the capabilities of the students. Instant "fossils" can be made by pressing shells into one of the dough recipes to obtain imprints.

While working with their shells the students will notice that some are white and chalky with worn edges while others are colored and shiny with fine sharp edges. The perfectly formed shiny shells were taken alive and command a higher market value among shellers. The chalky shells have been beach-worn but they still have value as specimens for study.

The delicate coloring and shine of shells can be preserved by rubbing the shell with a cloth dipped in mineral oil. Do not use vegetable oil which will attract insects to the collection.

Problem 3. SHELL STRUCTURE BANDS 2, 3

This lesson involving vocabulary has no precise beginning or ending. As a point of teaching efficiency, it is best woven into Problem 2 above and into other problems and conversations about shells wherever and whenever students need to know a term by which to call a structural part.

Problem:

What are the names of parts of a shell?

Suggested Procedures.

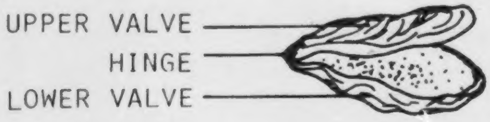
Visit the students at their desks or tables while they are at work making reconstructions of shells (Problem 2). As they remark or ask about "this bump in here," or "the pointed tip up here," offer the name of that part. When shells are being sorted in Problem 4, further opportunities will arise for learning the names of shell parts.

The diagrams below can assist in clarifying names for shells. At an appropriate time the diagrams might be put on the board or perhaps duplicated with a copy given to each student.

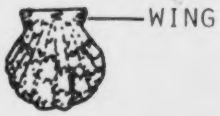
The list of terms attached to the diagrams are more extensive than are needed by the younger students. Select those which are appropriate to the given grade level and interest.

Teacher Background Information.

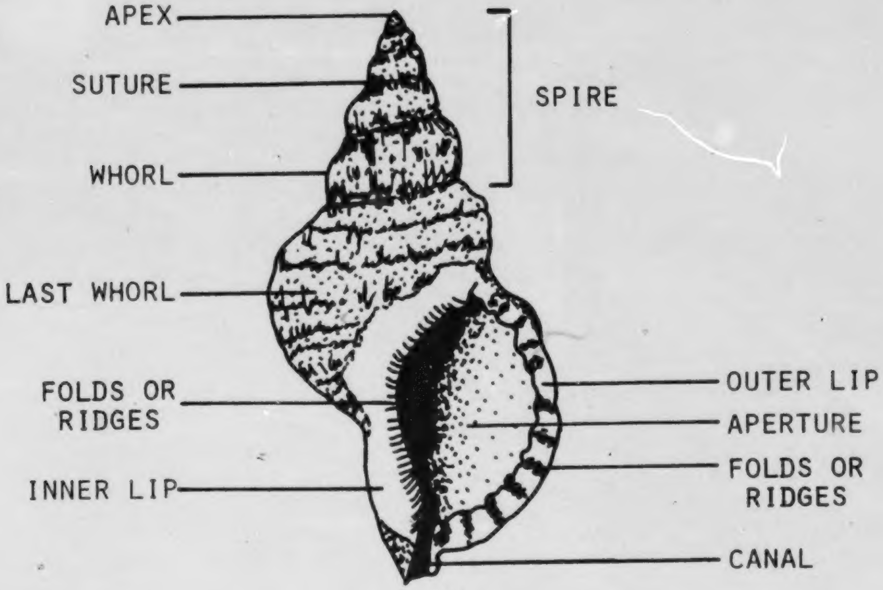
1. Two-piece shells are called BIVALVES, or PELECYPODS



The two valves open and close by means of a muscle at the hinge. Some bivalves have extensions on both sides of the hinge called WINGS.



2. One-piece shells or snail shells are called UNIVALVES or GASTROPODS



The tip top point of the shell is the APEX.
One complete turn or coil is a WHORL.
Grooves between the whorls are SUTURES.
The whorls which form the top of the shell are called the SPIRE.
Most of the snail lives in the LAST WHORL.
The hole or opening is the APERTURE.
The outer edge of the aperture is the OUTER LIP.
Folds found on one or both lips are RIDGES.
The groove leading from the inside of the shell out to the base of the shell is the CANAL.
The rounded bumps on some shells are called TUBERCLES or GRANULES.
Sharp, pointed extensions on some shells are called SPINES.
A rounded, shelly or horny "trap door" of the aperture is called an OPERCULUM.
The operculum of the Turban Shell is called a CAT'S EYE.

Hold a shell with the spire up and the base down. Look down on it from above and follow the spiral from apex to aperture. If the whorls coil in a clockwise direction, it is a RIGHT HANDED SHELL. Most shells are right handed. If the whorls coil counterclockwise, it is a LEFT HANDED SHELL.

Problem 4. SORTING SHELLS

BANDS 2, 3

Many people, including young people, demonstrate an innate desire to put things in order. During Problem 1, which aimed at no more than awareness, some students may already have remarked on the likenesses and differences among certain shells, or wanted to place them in similar groupings.

Problem 4 gives students an opportunity to exercise their tendency to order things.

In this problem the students are asked to group shells according to their own ideas before being exposed to the standard scientific classification system for shells. Students often find greater sympathy and agreement with the official system after they have labored a bit at classifying on their own.

Problem:

Put into separate groups those shells which seem to match or go together.

Suggested Procedures.

1. Before class, divide the class collection of shells, pictures of shells, and molded replicas of shells made by the students, into piles, with representatives of as many different shell types as possible in each pile.

2. Divide the students into working groups and give one pile of shells to each group.

3. The challenge to the class is: "Group together the shells which seem to go together." Give no instructions as to how to group the shells. If the students ask for directions the answer is: "Group them anyway you like. It's up to you."

4. Allow time for the students to work through the assignment. The length of time needed will depend on the number of shells in each pile, and on the interest and ability of the students. Some possible criteria the students use might be:

   -Grouping by condition of shell: broken shell bits, beach-worn shells, "new" shells.

   -Grouping by size: small, medium, large.

   -Grouping by color.

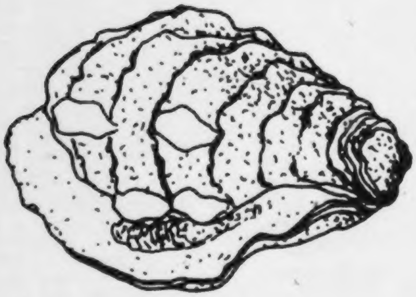
   Etc.

5. Have each group report and demonstrate to the class the grouping it decided to use. Try to maintain an atmosphere of appreciation and approval for whatever criteria each group chose to work by. All should be equally accepted and admired.

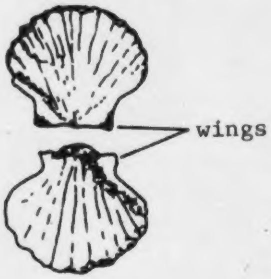
6. Tell the students that the scientific system of classifying shells is to sort them by shape or structure into groups called Families. This does not imply that the student systems of sorting are useless. The official system is simply the one that scientists have come to agree on and is useful as a standard international system.

The diagrams below may be reproduced and copies given to each student to serve as a guide for sorting the class shells again, this time according to their scientific families. The diagrams are purposely only outline sketches to show family characteristics. It should be sufficient at the elementary level for students to learn family names of shell groups (Cone, Cowrie, Conch, etc.), rather than try to identify specific shells by genus and species. By way of exception, one or two particularly interesting shells may be tracked down to genus and species names in a reference book. Most local libraries contain books on shells having colored photographs and descriptions to aid with identification.

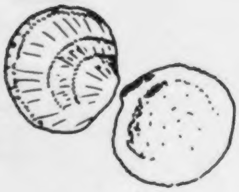
FAMILIES OF BIVALVES



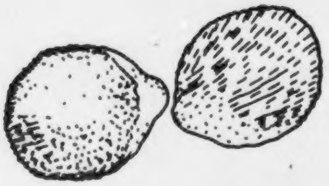
OYSTERS



SCALLOPS
OR
PECTENS

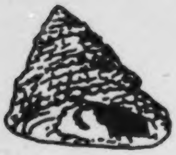


CLAMS

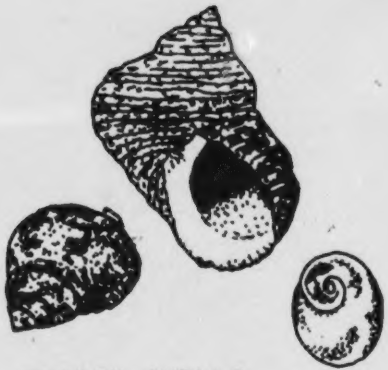


COCKLES

FAMILIES OF SNAIL SHELLS

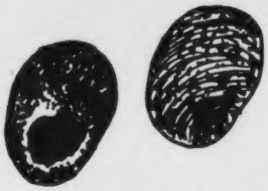


TOP SHELLS
(pearly interior)

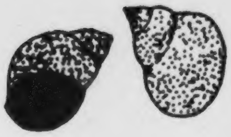


TURBAN SHELLS

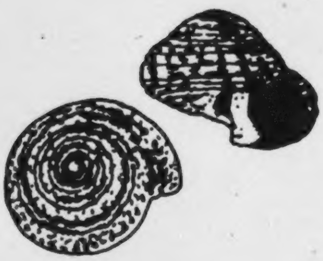
(operculum = cat's eye)



NERITES

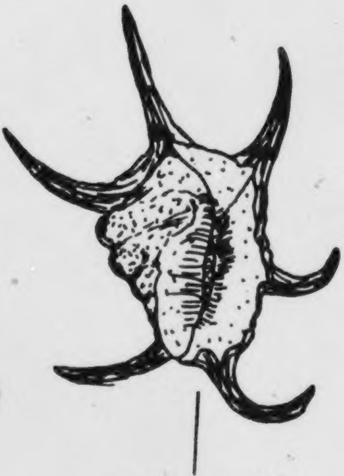


PERIWINKLES



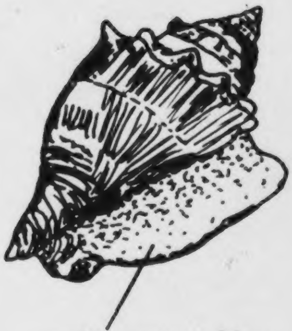
SUNDIALS

STROMBIDS
OR
CONCHES

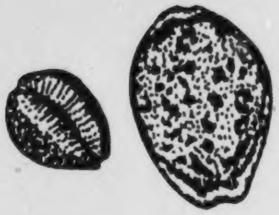


spider conch

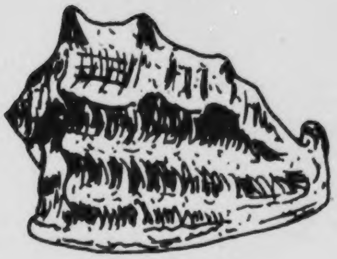
(not a Hawaiian species
but often included in
shell collections)



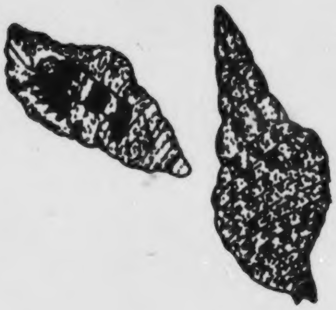
wide outer lip



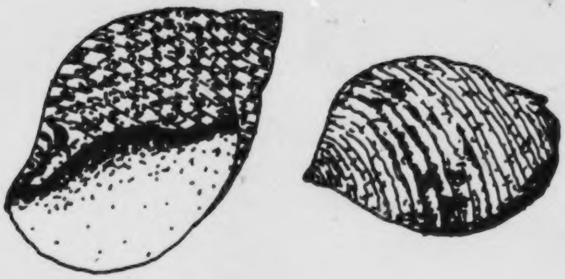
COWRIES



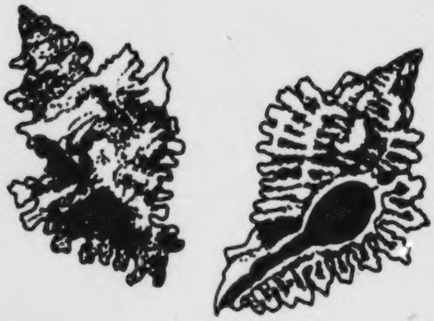
HELMET SHELLS



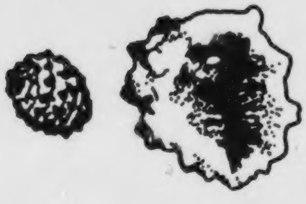
TRITON SHELLS



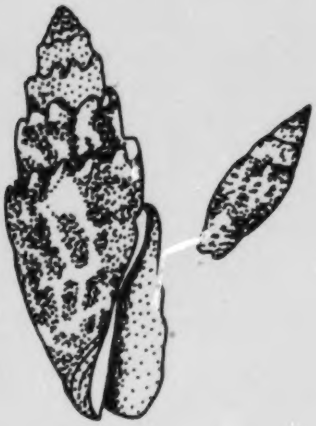
TUN SHELLS



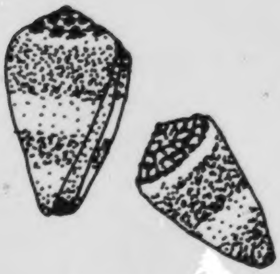
MUREX SHELLS



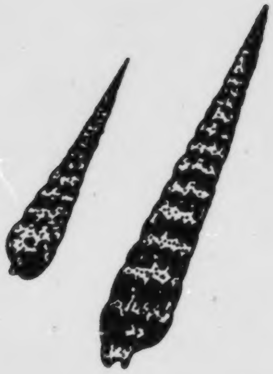
ROCK SHELLS AND DRUPES



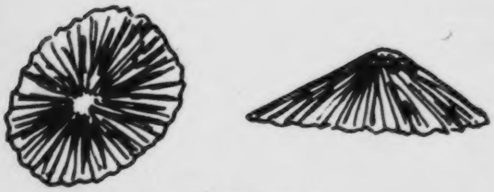
MITERS



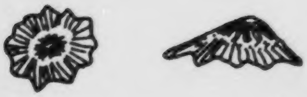
CONES



AUGERS



LIMPETS



SIPHONARIA
(Sometimes called False Limpets)

Optional Activities.

After the students have finished sorting their shells by family groups, you might use a "vocabulary game" to help with the remembering of shell family names. Supply specimens for the games by pictures, the clay of paper reproductions made by the students, and/or beach worn specimens you may have.

1. The "Name That Shell" Game:

   Put a collection of shells in the center of a table with students seated around the table. Each student, in turn, reaches blindly into the pile of shells and picks one up. He opens his eyes, looks at the shell, and announces its family name. If he is correct he may claim the shell for his own stockpile. If he does not know the name, he puts the shell back in the central pile. After 10 minutes (or ten turns around the table, or whenever you decide), the student with the largest collection of shells at his place is the winner. An appropriate prize might be for the winner to keep one shell of his choice for his own.

2. The "Shell Trading" Game:

   Give each student 10 small pieces of wrapped candy plus ten randomly selected common shells in a bag (or in two bags). The students mill around to negotiate as many transactions as possible in the time alloted (perhaps 10 or 15 minutes). To negotiate a trade, a student takes a shell from his bag and offers it to a second student saying, "I'll trade this shell for a piece of your candy." If the second student knows the name of the shell, he says, "No, thank you, I don't like ______________." (He names the shell by family.) If he cannot name the shell he must accept the shell and forfeit a piece of his candy in exchange.

   At a signal indicating the end of the open trading period, each student may eat whatever candy he has in his bag. Those who knew the most shell names have the most candy to eat.

3. "Calling All Shells" Game:

   Give each player the same number (perhaps 10 or 15) miscellaneous common shells kept secret in an opaque bag. If possible, each shell in the bag should be of a different family. Ideally, each bag will have identical contents but this is not essential. Three to eight players sit around a table with their bags of shells hidden in their laps. The object of this game is to get rid of the shells in the bag.

   The first player selects a shell (e.g. a small cone shell), hides it in his fist, extends his fist toward the center of the table, and calls out, "Calling all cones!" All other players search in their bags for cones which they secretly hide in their fists and then extend their fists out toward the center of the table. When the leader sees that each player has a closed fist on the table he calls out "Show your cones!" whereupon everyone opens his fist revealing the shell he is holding. All the correctly selected shells, in this case cones, may then be placed in the center of the table. Students holding shells which are not cones, must return their incorrectly named shells to their own bags.

Then player number two becomes the leader. He selects a shell from his bag, holds it hidden in his fist on the table, and announces "Calling all ____________," (naming the shell family). The other players search in their bags for a shell of the family called to put into their fists. A student who cannot find a shell in his bag of the kind called for, places his empty fist on the table with all the others, simulating that he is holding a shell. When the leader notes that all fists are on the table he calls for a show of shells. Correctly selected shells are left in the center of the table. Incorrectly selected shells are returned to the individual's bags. A variation is to have players with empty fists be penalized by having to take an extra shell from the central pile and add it to their bag, thus delaying their goal of getting rid of shells.

The game ends when one player succeeds in getting rid of all the shells in his bag, an accomplishment dependent upon being able to select the proper type of shell for each family name called for.

The winner may have the honor of having his name posted on the board as a "Shell Master." There might be a play-off among shell masters.

Additional Teacher Information.

Only two classes of mollusks are given in the illustrated list above: the snails or Gastropods, and the bivalves or Pelecypods. Within these two classes are hundreds of shell families. Fewer than two dozen families are listed here. Other groups of mollusks not mentioned include the tusk shells (single shells shaped like tiny elephant tusks), chitons (with eight shelly plates), squids and octopi (with no shells), and sea slugs, including Aplysia and nudibranchs taken in a separate topic.

Limpets are water breathers and live on the rocks at or below the splash zone. Siphonarias are small, flattish, deeply-grooved, limpet-shaped air breathers and cling to the shoreline rocks above the water line. The sure test of whether a small dome-shaped shell on the rocks is a limpet or a siphonaria is to pry one off and look at the underside of the soft body. The siphonaria, being an air breather, has a small tube at one side which unfortunately is not easy to observe.

Problem 5. BUBBLING SHELLS

BANDS 1, 2, 3

Chemically, sea shells are calcium carbonate, as are coral skeletons, coralline algae (reef builders), pearls, blackboard chalk, and mother-of-pearl buttons. Hawaiian sand and sandstone originate from the materials of the reef and hence are predominently calcium carbonate.

Calcium carbonate ($CaCO_3$) in contact with vinegar, or any other weak acid, reacts chemically, releasing carbon dioxide accompanied by visible bubbling and bumping about of the small bits of calcium carbonate in the vinegar solution.

The three questions of Problem 5 are listed separately. The youngest children will find Part 1 an interesting phenomenon to watch and for them the experiment can end there.

Upper level students need to work through Part 1 before going on. Because the wording of the succeeding questions gives away the preceding answers, the three questions of Problem 5 are put into separate boxes. How far to go into the chemistry of calcium carbonate can be determined by the teacher as the work progresses.

Materials.

- *Vinegar*
- *Other weak acids and common household solutions*
- *Small flat containers (petri dishes or jar lids)*
- *Tiny bits of shells and other calcium carbonate articles (coral, chalk, beach sand, gravel, pearl buttons)*
- *Other bits of items to test ad libitum*

Problem 5, Part 1: BANDS 1, 2, 3

Put broken bits of shell in vinegar. Observe the reaction.

What else, besides sea shells, react in this way in vinegar?

Suggested Procedures.

1. Give each working group of students a flat dish or jar lid containing a small amount of vinegar.

2. Have the students begin by placing two or three tiny bits of shell, preferably operculae, in vinegar. In a few moments bubbles will form. Bubbles forming underneath small flat pieces of shell cause the pieces to move. Heavier pieces of shell remain in place but emit bubbles.

3. Have the students try some "unknowns" such as tiny bits of coral, Hawaiian beach sand, small beach pebbles, pearl buttons made of shell (not plastic).

   For testing bits of blackboard chalk use a separate container because the reaction of chalk with vinegar is so rapid the solution quickly becomes clouded, obscuring the view of other objects.

   The cessation of bubbling after a time may be caused by the chemical reaction having gone to completion. Fresh vinegar may be needed.

4. Having observed the reaction of items suggested above, students might be encouraged to try other small items of their choice such as bits of eraser, black sand, bits of dark rock, tips of lead pencils . . . anything.

5. What characteristics do all the things which react in vinegar have in common? Can the students find a common denominator among things which produce bubbles?

   Three tentative conclusions to this problem, hopefully arrived at by the students with minimum help, are: a) all the objects which bubble seem to be white; b) they are all somehow associated with the beach or reef; and c) these white beach products must all be made of, or all contain, the same material.

Problem 5, Part 2: BANDS 2, 3

Will white beach items which bubble in vinegar, bubble in other liquids?

Suggested Procedure.

1. Provide the students with some weak acids such as lemon juice and dilutions of any weak laboratory acids available to you. Also encourage the students to try other liquids. They might think of tap water, salt water, soda pop, laundry detergents, clorox, household cleaners, etc.

2. Make a prediction before each new liquid is tried. For example salt water might be predicted not to produce bubbling because if it did our beaches would constantly be in a lather. After noting that lemon juice produces a reaction, it might be predicted that perhaps orange juice might react. Students may have their own ideas as to whether or not the various detergents and household solvents might work. Test each prediction.

3. Can the students find a common characteristic among liquids which cause bubbling, as opposed to liquids which do not produce bubbling? Students might arrive at an over-simplified statement such as "Vinegar and citrus juices cause bubbling whereas detergents and cleaning fluids do not."

   The chemical answer is too sophisticated to burden the students with, but may be of help to the teacher.

$$\underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{any acid*}}{2H^+} \xrightarrow[\text{by double replacement and decomposition}]{} \underset{\text{a calcium ion}}{Ca^{++}} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide which bubbles off as a gas}}{CO_2 \uparrow}$$

*An acid salt which releases a reduced number of free hydrogen ions (such as clorox) may also produce a weak reaction with chalk but the replacement reaction is too slow and weak to produce bubbling with the more compacted shell bits and sand.

Problem 5, Part 3: BAND 3

If you found a piece of white rock in your yard or far from the beach, how could you test to find out if it was related to white beach materials?

The obvious answer which students may offer to this problem is to test whether a chip of the white stone will bubble in vinegar. If it does, then it may have in it, or be made of, the same or similar material as the white beach items which bubble in vinegar. Letting stand overnight may be necessary.

In Hawaii, the chances are good that white stones picked up anywhere on the island are of reef origin. Construction dredging and land fill often result in reef materials being brought far inland. Certain types of volcanic eruptions, such as at Hanauma Bay, exploded through ancient reefs, bringing up bits of coral visibly embedded between the lava. Quarry rock is sometimes carbonate materials deposited eons ago in a sea which has since receded while the land rose. By contrast, white rocks common on the Mainland are often quartz or feldspar and of course will not bubble in vinegar.

It is left to the teacher whether or not to tell the students that the white beach material which bubbles in vinegar is CALCIUM CARBONATE. Calcium carbonate is manufactured by sea animals and plants such as corals, sea shells, foraminifera, and coralline algae.

This set of problems about "Bubbling Shells" provides good content for a formal science notebook report. It includes a problem to state, tests, data, and a conclusion. See the PROGRAM MANUAL for reporting format.

Problem 6. THE MAKERS OF SHELLS BANDS 2, 3

Sea shells are products of living animals. Animals which make sea shells are found from beachline to depths of several hundred meters. Some species occur in greater densities off shore, others at greater depths.

Our shore-bound elementary students cannot get to where most sea shells live. Near-shore species which they can reach need, for the most part, to be conserved. How, then, shall our students study living mollusks?

One means is to observe small tide pool snails, as they do in studying the nerites and periwinkles.

Another means is to observe land snails and garden slugs. The largest land snail in Hawaii is the giant African snail, which is kapu for study. African snails are carriers of rat lung worm disease which in humans is a form of encephalitis, a disease always serious and sometimes fatal. On no account should African snails become a part of classroom study nor be handled by the students or teachers. The small attractive land snails inhabiting our Hawaiian forest areas are harmless but they are prized endangered endemic species so they should be left alone also. That leaves for study among the land mollusks, the garden slugs and the small garden snails found in the top soil or on plants in the early morning dew.

A third, and seemingly best source, of mollusk body study materials is the local fish market. Oysters, and clams, are readily available, even though they must be purchased. Opening and looking at these mollusks, even in quantity, does not endanger wild populations because market shellfish are raised or caught for commercial use within fish and game limits.

At this elementary level, the soft bodies of mollusks need not be considered in microscopic detail. The purpose here is rather to have the students recognize that mollusks are living animals. A shell is the "house" produced by the animal's soft mantle.

Problems:

What kind of animal lives in a bivalve shell?

What kind of animal makes a snail shell?

1. BIVALVES

Materials.

-Oysters or clams in the shell purchased from a local fish market
-Hammer, screw driver, old knife, or other shell-opening device
-Hand lenses
-Copies of mollusk diagrams (below) for each student
-Newspaper on which to work
-Clean-up rags

Optional:

-Pot of boiling water
-Salt or other shellfish seasoning

Suggested Procedures-in-Brief.

1. Secure oysters and/or clams from a fish market. Keep in ice water or in refrigerator until time for class use.

2. Get the opening of the shells started to the point where the students can complete the opening process. Distribute shells to students.

3. Have students examine animal anatomy and identify a few parts with the help of a hand lens and the diagrams (see below) of bivalve anatomy.

4. (optional) Eat, or at least taste, the shellfish.

5. Notebook reports.

Procedures-in-Detail.

1. Secure oysters and/or clams from a fish market. Keep them in ice water or in a refrigerator until time for class use.

2. Start the opening process sufficiently so the students can complete the task. Oyster shells can be broken around the edges with a hammer and then pried apart slightly so that students can insert a knife blade to cut the muscle from the shell and finish the opening process. Clam shells might be loosened by forcing a screwdriver or heavy knife into the hinge. Clam shells pop open when immersed in boiling water for about five minutes.

   Have the students work with clean hands and clean instruments so that the meat might be tasted afterwards, if desired.

3. Hand lenses and the diagrams below can help students to identify a few parts of the internal anatomy. A detailed study is not necessary. The point is to notice that bivalves are animals with some common body parts.

OYSTER

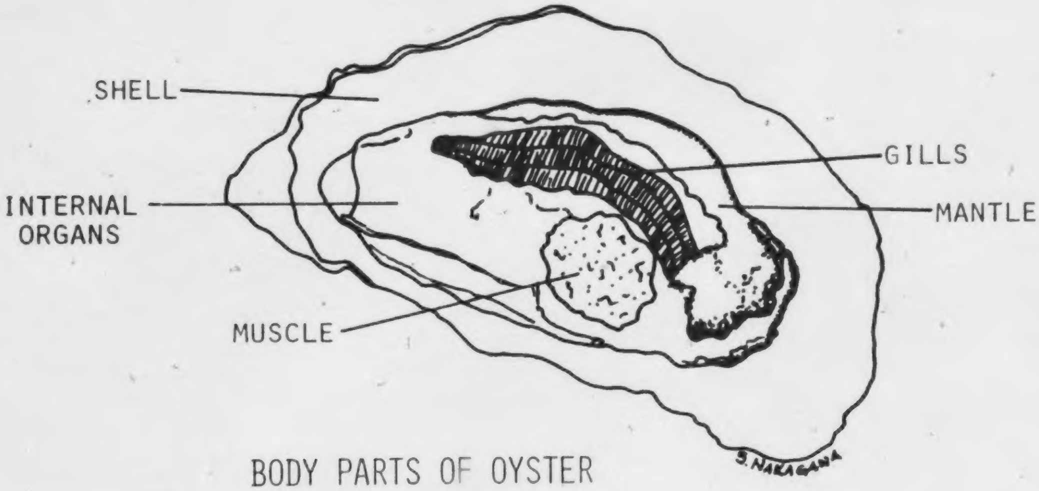
The MANTLE is a delicate, white membrane with frilly edge resting against the inside of the shell. The mantle is what manufactures the shell of the animal.

The two MUSCLES are firm, white, gristle-like, circular attachments to the inside of the shells. These muscles allow the animal to open and close its shell.

The GILLS are several layers of thin "leaves" showing fine lines. Shellfish breathe by means of pumping water through the gills. The water contains oxygen which the gills filter out.

The DIGESTIVE GLAND and GONADS of the oyster are the prominent, whitish bulge which takes up most of the space in the back part of the shell.

Notice that the bottom shell of the oyster is deeper or more scooped out than the top half. Barnacles and other shelly attachments may be growing on the outside of the oyster shell.


SHELL
GILLS
INTERNAL ORGANS
MANTLE
MUSCLE
S. NAKAGAWA

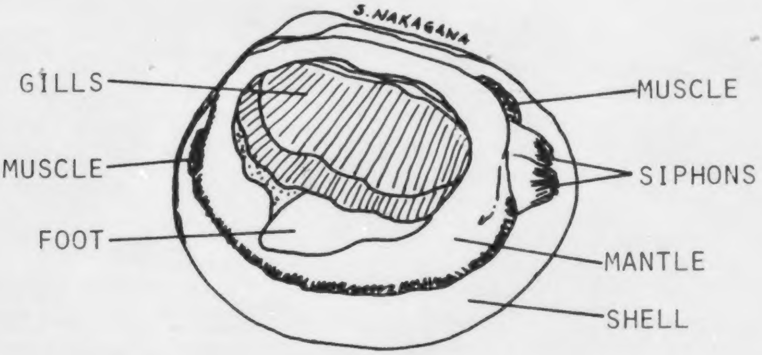
BODY PARTS OF OYSTER

CLAM

Notice where the MUSCLE is attached to the shell on both sides of the hinge.

Find the MANTLE and GILLS as in the oyster. Two SIPHON openings, or water canals, extend toward the side of the shell.

The FOOT is a salmon-colored or pale yellow, tongue-like organ at the center front. The clam can extend its foot out of the shell and give itself a push against the sand or rocky bottom on which it is resting.


S. NAKAGAWA
GILLS
MUSCLE
MUSCLE
SIPHONS
FOOT
MANTLE
SHELL

BODY PARTS OF CLAM

4. (optional) Encourage the students to taste a bit of bivalve muscle. A little salt or other seasoning might help. Many people eat the entire oyster or entire clam body in one big bite. Try it! If you wish, you may boil the animal for about five minutes before eating. For seasoning, use salt, lime juice, cocktail sauce, or other shellfish relishes.

   If you have an extra unopened oyster or clam, you might put it in the classroom aquarium. If it fails to show any signs of life within 24 hours, such as opening slightly or closing when touched, it should be removed.

5. Notebook reports might consist of the given diagrams pasted into the students' notebooks with added student comments.

2. SNAILS

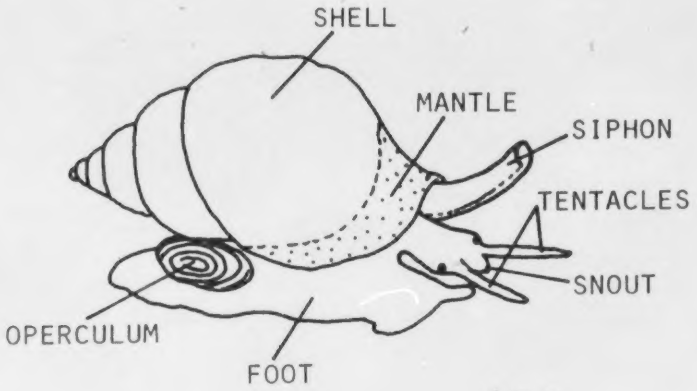
Materials.

Ask the students to look for small garden snails or shell-less garden slugs in the early morning or in rainy weather. (No African snails!) Some of these might be brought to school for more careful observation. Tide pool snails can be used but their shells almost completely cover their bodies so that there is very little body to be observed in the live animals.

Suggested Procedures.

Look for the following body parts on the snail while it is actively crawling. The slug is similar but lacks a shell.

SNAIL BODY PARTS



The OPERCULUM at the back of the foot is the part which forms the "door" when the snail is withdrawn into its shell.

The MANTLE membrane is the "maker" of the shell, just as the skin of our fingers is the maker of our fingernails. The mantle is also the protector of the shell while the snail is alive. In sea shells the folds of the mantle partially, or sometimes completely cover the outside of the shell while the snail uses its large foot to crawl over a rock or through sand.

Make a notebook report of snail body parts with a diagram of the particular snail or slug which was observed.

Problem 7. VARIATIONS WITHIN A GROUP BAND 3

Every living thing, while sharing likenesses with others of its species, is unique. Similarities and differences of characteristics possessed by members of a related group provide the basic data for the science- of genetics, taxonomy, evolution, and an array of research pursuits involving statistics, distribution patterns, deviation from the norm, and other calculations.

All these are far above the scope of elementary student ability, but a rudimentary awareness of the basic concept is not. What is aimed for in this problem is a simple acquaintance with the idea that related members of a group display individual differences, and that these differences can be shown in "a line up" or a simple bar graph.

The traditional laboratory subjects for study of variation have been Mendel's peas, Drosophila flies, and similar large controlled populations. The time, daily care, equipment, and skill needed for handling and tracking such living populations are too difficult in elementary school. But sea shells are products of living organisms which display similarities and differences typical of living things, while at the same time they require no food or water, are a convenient size to handle and observe, give consistent data from day to day, and can be sorted as easily as a collection of shells.

Problems:

If you put together shells of the same family (or same genus or same species), what small differences can you find among them?

Line up shells of one group in order, so that the extremes of their differences are at the two ends of the line.

Make a bar graph showing the distribution of differences within one shell group.

The procedures below suggest beginning with looking at differences among members of the student group, going from there to observing differences among a shell group, then drawing some general conclusions about individual differences. The problem could just as easily be done the other way around, i.e. begin with noting differences among the shells, then note differences among the students, then draw some general conclusions. A third appraoch is to omit the people differences and work only with the shells. The teacher who knows the ability of the class at hand will know best which course to pursue and how much, if any, of the graphing and mathematical work to get into.

Suggested Procedures-in-Brief.

1. Introduce the topic by noticing some human likenesses and differences among members of the class.

2. Stand the students in line along a gradation of differences. Graph the differences on the board to show distribution patterns, norms, etc.

3. Select a group of related shells and line them up according to individual differences along a spectrum of small changes.

4. Make a bar graph of differences found within one group of shells.

5. Discuss whether a gradation of differences among people and shells may be a universal phenomenon of living things. Probe some reasons for this phenomenon.

Procedures-in-Detail.

1. Discuss likenesses and differences among people.

   For likenesses, note that everyone has two eyes, two ears, one mouth, and whatever else it takes to identify a human being.

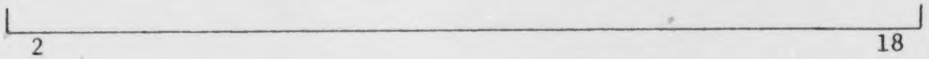
   For differences, consider the ways by which we can tell one person from another: shape of face, hair color, tone of voice, body contours, behavior patterns, etc.

   Some students seem more alike, others less alike. We could arrange students in a line, with those most alike together.

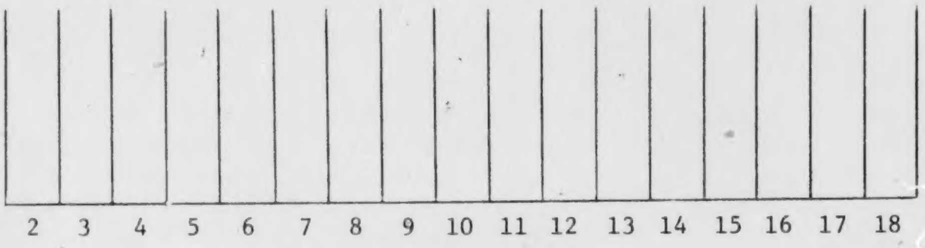
   Select one characteristic easy to array in a spectrum, e.g. height of students, hair lengths, coloring, shoe size, length of little finger, or whatever. Suppose we use hair length as an example here.

2. Ask the students to line themselves up in order, with the longest hair at one end of the line and the shortest hair at the other end. Difficulties may arise because of many students having hair of similar length, or one student having hairs of many different lengths. Set standards as to whether to go by the average length of a students hair or by the single longest hair on his head. Rulers may have to be brought out to settle moot questions.

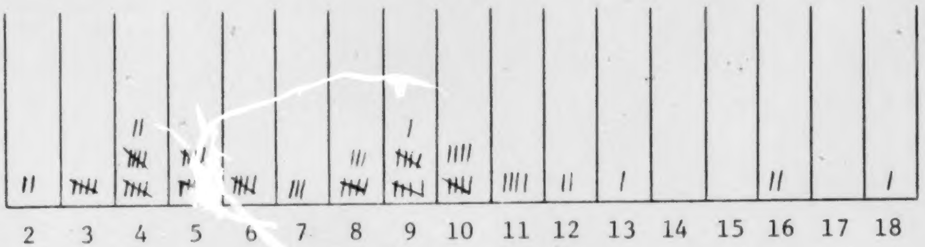
Next, draw a line on the board. At one end of the line indicate the hair length of the shortest-haired student to the nearest inch. Suppose it is two inches. At the other end of the line indicate the hair length of the longest-haired student. Suppose it is 18 inches. The line on the board will look like this.



Divide the line into even divisions, each division to represent one inch. The line on the board will then look like this.



Each student, probably with help from his neighbor, should determine the length of his hair to the nearest inch and place a mark in the appropriate column on the board. Some columns will have only one student, some may have none, some columns may have several or many students.



Build the columns into a bar graph, the height of each bar represents the number of students in that column.

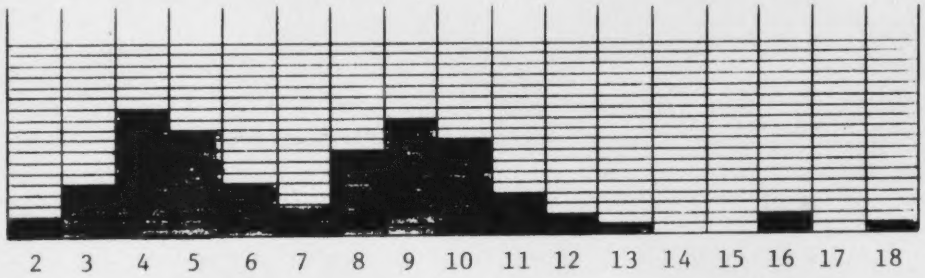


TABLE 1. DISTRIBUTION OF GRADE 5 STUDENTS IN OWYHEE SCHOOL BY HAIR LENGTH.

Interpret the graph.

In the case of the above problem, we seem to have two populations of students: those whose hair is mostly four to six inches long, and those whose hair is eight to ten inches long. The mid-point between two and 18 is 10 inches, but obviously the majority have hair which is shorter than the half-way number. The hair length of the student in the "middle" (75 ÷ 2) is seven inches, which is also the "short" side of the half-way point. Those three students with the very long hair seem to be skewing our calculations of the average and median points away from the norm. The teacher may or may not wish to introduce terms such as median, norm, deviation, etc.

Instead of hair length, use height or any other variable characteristic as desired.

3. Give each group of students a pile of related shells. For example, one group could work with cowries, another with cones, another with periwinkles. Using the experience above, ask the students to line up the shells according to any one characteristic of their choice. They might choose length of shell, number of whorls, number of ridges, height of spire, or whatever seems to demonstrate some variability within a common character.

4. Graph the shell data similarly to the method shown above for hair lengths.

   Each student group could report and explain its results. Some graphs may be narrow and steep; others may be spread out showing wide variation of the chosen character. If there is a double hump, as in the hair lengths, there may well be a mixture of two different species of shells in the pile.

5. Discuss what the variations found in the students and those found in shells have in common.

   -Do both people and shells show variations within a given character?

   -Might other living things show such variations of some character?

   -Do non-living things show a pattern of variation? (Rocks certainly vary in size but not with a bell-shaped distribution around a norm.)

   -Is it possible that variations within a group is something that goes with being alive?

   If the students can reach a conclusion that living things possess individual differences within a related group, they will have grasped, at least in embryo, one of the most basic concepts of biology.

6. Compose a notebook report of the problem with bar graphs and conclusions.

Problem 8. SHELL COLLECTIONS

BANDS 1, 2, 3

Activities:

Visit the shell displays at the Waikiki Aquarium.

Visit a shell show of the Malacological Society or any other shell displays when they occur.

Look at the shells and shell items for sale in shops.

When taking the students on a field trip to the Aquarium or Shell Show, you will know if you have prepared them for a fruitful visit if you hear them making such remarks as "I never knew there were so many different kinds of cowries," "Look! a cone shell just like ours only lots bigger and shiny," "We didn't have any shells in our collection like this one," and so on and on.

For making arrangements for visiting public displays, see Section I in this book under the titles of "Waikiki Aquarium" and "Extended Field Trips". Besides class visits, students can be encouraged to visit shell displays with their parents on weekends. Watch for advertisements of shell shows by the Malacological Society and other collectors so you can call them to your students' attention.

If the students have become interested in and knowledgeable about shells through class activities, they will begin to notice shells in many places, including in stores while on shopping trips. The souvenir sections of store shelves display shells as they are, as well as made into key rings, pendants, leis, wall hangings, and gadgets of all sorts. It might be interesting to put a chart on the wall on which the students can list all the kinds of things they have seen shells made into. By the end of a semester an imposing list of uses (and non-uses and mis-uses!) might be accumulated.

Problem 9. SEA SHELL ART

BANDS 1, 2, 3

Breathes there a soul who has not seen a cowrie shell made into a turtle with limpet shell feet and pipe cleaner joints?

Your students may enjoy making flowers, animals, pictures, mobiles, and what not else from shells and parts of shells. They may get ideas from things they see for sale in shops, or make up some shell art of their own.

A still life arrangement of shells can serve as a model for pen or pencil sketches, or a composition with water colors or pastels.

The rough textures of some shells can be made into rubbings by putting a piece of onion skin paper on the shell and then rubbing with pencil.

To obtain shells to work with, shop among the various hobby stores and floral decorator shops for shells and shell bits sold, if possible, in bulk. Hobby-making shells are not easy to obtain and they are not inexpensive.

An inexpensive shell activity is to go "mini" with shell art. Start with a shovel full of coarse beach sand. Sort from it tiny bits of coral, broken shells, sand grains of unusual shape, bits of dried sea weed. These can be pasted in artistic arrangement in one corner of a small white calling card or sheet of plain stationary.

The puzzle below may be of interest to some children.

PARTS OF A SHELL

Directions: Fill in the names of parts of a snail shell in the spaces pro-provided. The sentences below the diagram give hints on the name of the part. When the words are complete, the letters in the boxed spaces, reading downwards, spell what it is we are talking about.

1. ☐ ___ ___ ___ ___
2. ___ ___ ☐ ___ ___ ___ ___ ___ ___
3. ☐ ___ ___ ___ ___ ___ ___ ___
4. ☐ ___ ___ ___ ___
5. ___ ☐ ___ ___ ___
6. ___ ☐ ___ ___ ___
7. ☐ ___ ___
8. ___ ___ ___ ___ ☐

1. The pyramid-shaped top of a shell.
2. The "trap door" which covers the opening of a shell.
3. The opening of a shell.
4. Sharp, pointed extensions of some shells.
5. One complete coil or turn.
6. Notches or ridges on one or both sides of the shell opening.
7. The outer or inner edge of the shell opening.
8. The groove leading from the inside of the shell to the base of the shell.

8. APLYSIAS

Introduction.

Aplysias have the common name of sea slug or sea hare. Aplysias belong to Phylum Mollusca, the mollusks, along with sea shells and garden snails.

Most mollusks deposit hard shells, often very beautiful, around their soft bodies, as in cowries, cones, clams, and oysters. A few mollusks are without external shells, although some have a partial shell under the skin. On land, the shell-less mollusks are slugs, seen crawling in gardens at dawn. In the sea, the shell-less, or almost shell-less mollusks are nudibranchs and aplysias. The common Hawaiian species dealt with here is Aplysia juliana.

Aplysias offer two educational opportunities in the elementary classroom:

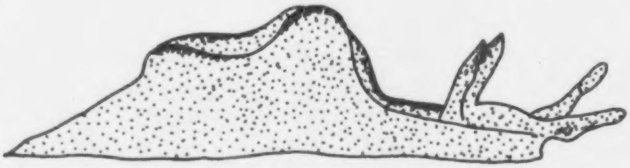
1. They are fun to watch, giving opportunity to learn about their form and behavior, and

2. They make good subjects for an experiment on how much green food makes how much animal body.

Appearance.

Aplysias may draw themselves into a rounded ball from less than ¼ inch to a few inches in diameter, or may extend into an oval shape when gliding or swimming. The color varies from pale green to light brown with grayish purplish blotches on the back. There is a small internal shell. In some species the back end of the foot has a prominent sucker. "Horns" (rhinophores) protrude from the head. The horns, said to resemble rabbit ears, account for the name sea hare.

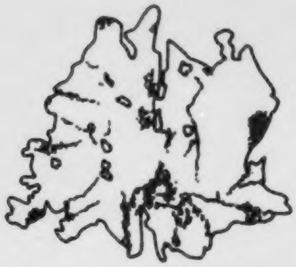
APLYSIA
JULIANA



Aplysia juliana may spew out a white liquid when disturbed. Other aplysias may spew purple. Aplysias do not bite and are harmless to handle, but they do have toxins and so should not be eaten.

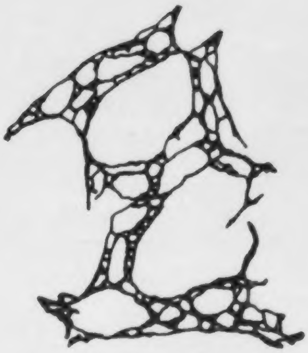
Field Collection.

Look for aplysias in the folds and around the base of sea lettuce (Ulva), or in the sand below it. Ulva, with its bright green, flat sheets may be attached to rocks or may be floating in bunches near shore. Several varieties of Ulva are found in Hawaii. Aplysias seem to thrive best on Ulva fasciata or its close allies.



ULVA FASCIATA

Look also in Ulva reticulata. This sea weed consists of narrow, flat, tangled ribbons, light green, with holes in the ribbon.



ULVA RETICULATA

To collect aplysias, pick up a clump of Ulva and place it in a bucket of sea water. Look in the folds of the sea weed. Shake the sea weed vigorously to see if a specimen or two might drop out. Sieve through the sand below the area where Ulva is clumped.

Both Ulva and Aplysia seem to be seasonal. A reef which is barren at one time of year may yield specimens at other seasons.

Oceanic Institute and some other laboratories engaged in culturing herbaceous fish are sometimes plagued with sea slugs (Aplysia or Stylocheilus) multiplying in tanks, thriving on sea weed intended for the fish. If these institutions have aplysias, they are usually glad to give as many as are wanted to a teacher for class use.

Laboratory Maintenance.

Aplysias require well oxygenated salt water and are sensitive to pollution. For Aplysia, the class tank needs a good, operating, filtration system. Aplysias seem to live compatibly with most other tank inhabitants.

For food, provide an abundance of fresh or fresh frozen Ulva fasciata. See story about fresh-frozen Ulva at the end of this topic. Aplysias will eat the ribbon-shaped Ulva reticulata but they do not seem to thrive on it. Unless they are very small, keep only one specimen for observation in the class tank. This is not only good conservation but one large Aplysia is about all the class tank can support, considering their huge appetite for Ulva. However they may go a few days without Ulva and then make up for it later by eating large quantities.

Investigations with Aplysia.

Problem 1. APPEARANCE (in general only) BANDS 1, 2, 3

This is intended to be a field problem. However if field work is impossible, one or a few aplysias could be maintained in the class tank while the observations are made.

Problems:

What do sea slugs look like? Make a sketch.

What is their size, shape, color?

Suggested Procedures-in-Brief.

1. When you find a rich Aplysia site, plan a Short Field Trip, or include Aplysia observation as part of an Extended Field Trip (see Section 1 on Field Trips).
2. In the field, have the students look for the animals and observe them in their habitat.
3. Bring one animal back to the class tank for closer observation of feeding and locomotion and as a model for sketching.
4. Discuss appearance, behavior, and have older students make notebook reports.

Procedures-in-Detail.

1. Preparation.

Keep an eye out for aplysias whenever visiting the reef. When you find an area which seems to have a fair abundance of them, take up this lesson.

Prepare the students for a Short Field Trip to observe aplysias (see Section 1 on procedures for Short Field Trips). An alternate idea is to include Aplysia observation as part of an Extended Field Trip (see Section 1 on Extended Field Trips).

Tell the students how and where to look for aplysias as described in the Introduction above. Show a picture or tell only enough so that the students know what to look for and where. The details should come as far as possible from their own observations.

2. Field Activity.

Look for aplysias in the Ulva and in the sand below it. Put a few aplysias in a bucket or a shallow pan of sea water and sit on the beach with them. Watch them crawl, swim, and roll into a ball when disturbed. If there is time, make a sketch there at the beach.

Take a careful look at the general habitat in which they are found. What kind of area is it? What other plants besides Ulva are found there; what kinds of animals are there besides Aplysia? What is the depth of the water in the Aplysia territory? Is it rough or calm?

3. Classroom Follow-up.

It may be possible on an Extended Field Trip to finish the observing, sketching, and note-taking at the beach.

If observations were not completed at the beach, bring one Aplysia back to the classroom salt water aquarium, together with a supply of Ulva for food. Aplysias will not eat spoiled Ulva. The supply will need to be replenished from the beach every two or three days, or kept fresh-frozen. To fresh-freeze, place Ulva in water in an ice cube tray and place in the freezer section of the refrigerator. Feed one cube per day into the tank.

Students might take their turn making close observations at the class tank in between doing their other lessons over a few days time.

4. Discussion and Reports.

After an appropriate length of time spent on general observation, draw things to a conclusion and have the students complete their notebook reports on Problem 1. Here are some questions which might help with this:

-What does a sea slug remind you of? (jello? fresh-peeled litchi? garden snail?)

-What shape is a sea slug? What different shapes does it take as it crawls, rests, swims, sleeps, and hides?

-How do you think it can change itself into so many different shapes? (No skeletal structure) How does it fold its "side flaps"?

-How big is an Aplysia? How many centimeters long, wide, and thick? Should we measure it when it is resting in a ball or when it is stretched out? How can we get into the tank to measure? Is it all right to take it out of the tank? (very briefly, yes)

-Since the shape is so variable, can you think of a way to measure by some other means? How about weight?

-What color is an Aplysia (call attention to spots, shadings, and translucence).

- Aplysias are sometimes called sea hares. What is a hare? Can you see any rabbit ears on the Aplysia?
- Can you spell Aplysia? Sea slug? Sea hare? Mollusk?
- Did you find any Aplysia egg masses attached to the Ulva? (The eggs are an off-white tangle of "spaghetti" attached to the base of Ulva or, in the class tank, to a rock or aquarium glass.)

Problem 1 above was aimed at generalized, getting-to-know-you observations for students of all BAND levels.

The following problems are for upper elementary or BAND 3 students who have already had some experience with laboratory techniques, data analysis, and report writing. The problem questions are worded quite specifically so that students may go ahead and plan testing procedures themselves with minimal help from the teacher. Some hints or information are given in parentheses for teacher use only for guiding the students.

Problem 2. SENSES

BAND 3

Problems:

Can aplysias see? Do they have eyes? Will they turn toward or away from a narrow beam of light? Are they reacting to the brightness or to the warmth of the light? How can you tell? Test out your idea.

Can aplysias smell? Will they react to the presence in the water of different fish odors? Will they react to the presence in the water of juice squeezed from Ulva, even if no Ulva leaves can be seen? (see Problem 4 below.)

Are aplysias sensitive to touch? Are all parts of the body sensitive? Are some spots more sensitive than others? (Rhinophores are very sensitive.)

If you annoy an Aplysia very much, what does it do, if anything? (May spew liquid; see introduction.)

Problem 3. MOVEMENT AND ENVIRONMENTAL TOLERANCE

BAND 3

Problems:

Do aplysias swim? (They do in the ocean, less often in tanks.)

How do aplysias crawl? How fast can they crawl in inches or centimeters per minute?

(cont'd on next page)

Problems: (cont'd)

How and where do aplysias rest? Do they spend most of their time resting, swimming, or crawling? (They often bury themselves in sand.)

Are aplysias more active at night or in the daytime? How could you check without coming to school at night to observe?

What does an *Aplysia* do when you take it out of the water and place it on a wet surface? on a dry surface?

What does an *Aplysia* do if you change the water to be more salty? less salty?

What does an *Aplysia* do if you make the tank water slightly warmer? slightly cooler? How warm or cool can you make the water before the aplysia shows signs of discomfort? When it does show signs of stress what should you do? (Return conditions gradually to normal.)

Problem 4. FOOD AND FEEDING BAND 3

Problems:

Aplysias eat sea lettuce, *Ulva fasciata*. How do they eat it? Do they have teeth? Do they chew?

Given a choice between different varieties of *Ulva*, which does an *Aplysia* prefer to eat, or does he seem to distinguish?

Given a choice between *Ulva* and other types of sea weed, which does he prefer, if any? (The preference is for *Ulva fasciata*.)

If no *Ulva* is provided and other types of sea weed are, will aplysias eat the other sea weeds? If so, which kinds? (usually not)

Aplysias which have not been fed for a couple of days (e.g. over the weekend) often bury themselves in the sand in the bottom of the tank. Put some *Ulva* in the tank of some hungry aplysias buried down in the sand and see how long it takes them to discover that there is food in the tank. (If they are hungry the reaction is immediate.)

If you put only a very small piece of *Ulva* in the tank where hungry aplysias are buried in the sand, will they come after it? (yes)

If you put only *Ulva* juice in the tank where hungry aplysias are buried, can you get a reaction? (yes)

Problem 5. METABOLIC EFFICIENCY IN BUILDING PROTOPLASM BAND 3

Aplysias make excellent subjects for this problem. They thrive on one food, Ulva. Ulva can be weighed and will be entirely ingested by the Aplysia without loss from stems and side products. The Aplysia body is a hunk of almost pure protoplasm so that body weight gain is very nearly the same as total soft protoplasmic weight gain. The equation then becomes:

X grams of Ulva can be turned into X grams of Aplysia.

or, in general terms,

X grams of food can be turned into X grams of protoplasm.

Additional pluses for aplysias as laboratory animals for this problem are that they are easy to feed, easy to care for, easy to weigh, take up little laboratory space, and grow rapidly.

Problem:

How much Ulva does it take to increase the body weight of an Aplysia by a given number of grams?

Suggested Procedures.

Get the students to do as much of the planning as possible. You might help along with the following suggestions:

-Begin with small (young) aplysias so that growth will be more rapid and noticeable.

-Put each Aplysia in a separate tank (gallon jar) so that food intake and weight gain can be compared for each animal.

Aplysias need fresh, clean sea water. Put about an inch of clean sand in the bottom of each gallon tank and insert an air stone in the tank. Even better is a small, circular subsand filter in each gallon jar covered by at least an inch of sand.

-Feed fresh or fresh-frozen Ulva every day and weigh the amount put into each tank carefully.

-Feed as much sea lettuce every day as each Aplysia will eat without any being left over. This permits keeping track of how many grams are eaten. If any is left at the end of the day, fish it out and weigh it. Why weigh it? (So you will know how much was actually eaten.)

Take each Aplysia from the tank at about the same hour each day, roll it once across a dry paper towel to remove excess water, weigh it quickly, then return it immediately to its own tank or jar.

Make up a data sheet with three columns, one column for the date, one for how many grams of *Ulva* fed on that date, and one for daily weight of the *Aplysia*. If students have trouble coming up with a blank data sheet, here is one which could be used.

TABLE 1. WEIGHT OF ULVA CONSUMED VERSUS BODY WEIGHT OF APLYSIAS

Date	*Aplysia* #1		*Aplysia* #2		*Aplysia* #3		
	Food Eaten (grams)	Body Weight (grams)	Food Eaten (grams)	Body Weight (grams)	Food Eaten (grams)	Body Weight (grams)	etc

After about two weeks, calculate how many grams of sea lettuce it took to produce how many grams of *Aplysia*.

Discussion and Report.

Make a graph of the data with one line showing grams of food and one line showing grams of *Aplysia*.

- Did the aplysias grow an even amount each day. Did they grow faster when they were younger? When they were older?
- What was the proportion between grams of food eaten and grams of body weight gained?
- Did they stop eating or stop growing at any time? Did any aplysias die in the process? Could you determine the cause of death?
- Do you think gain of weight (i.e. turning food into protoplasm) applies to other animals as it does to aplysias?
- Do you think the food you eat produced weight gain in yourself in about the same proportion as it did in *Aplysia*? How could you find out?
- Now that your experiment is finished, what are you going to do with your aplysias?

Report on Aplysia Investigations by a Preliminary Pilot Class.

Aplysia Problem 5 was tried with a small group of students at the Laboratory School. Knowing that the work they were doing was a pre-test of materials to be written for teachers, two boys in the class asked to take the tests one step further. Said they, "We think the teachers are going to get tired of going to the beach so often to collect fresh *Ulva* for those hungry aplysias. We got tired of doing it. We would like to do some tests using frozen *Ulva*."

While the rest of the class went on to other new experiments, these two youngsters persevered on their own through three weeks of testing their ideas. They gathered fresh *Ulva* and froze it in the sections of ice cube trays. Some aplysias were fed only fresh *Ulva*, others only frozen *Ulva*. Then they switched diets. They also tried fresh and frozen *Ulva* at the same time in the same tank.

The excellent data these two boys generated showed clear evidence that frozen *Ulva* (thawed in the tank) seems equally acceptable and equally nutritious to *Aplysia* as *Ulva* gathered fresh daily from the sea. Their work is a real contribution to this Teacher's Guide since, as the boys were first to suggest, it permits handy storage of a couple of weeks of fresh food supply.

This is also an example of how students can become involved and carry through a significant experiment of their own devising.

References.

Herbert Fringe and Carl Fringe have described feeding and sensory responses of *Aplysia juliana*, giving further insights and ideas to those suggested in this topic. Their paper is published in the April 1965 issue of *Biological Bulletin*, Vol. 128, #2, 211-217, available at the University of Hawaii library.

Sea Hare drawn by Jason in Grade 1. May, 1975.

9. SEA ANEMONES

Introduction.

Three class divisions of Phylum Coelenterata are the Hydrozoa such as fresh water hydra, many marine colonial hydroids, and Portuguese Man-o-war, the Scyphozoa or jellyfishes, and the Anthozoa which include sea anemones and most of the corals.

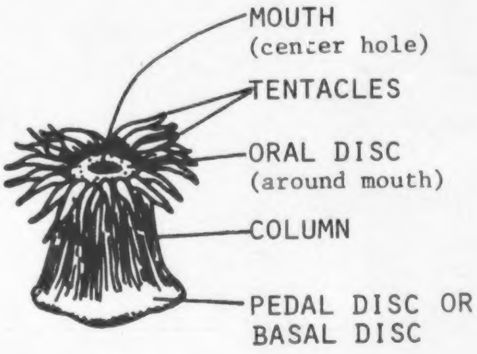
Coelenterates are generally soft-bodied marine animals with hollow body cavities (the coelenteron). Their tentacles are embedded with stinging cells armed with nematocysts which are discharged into prey.

Investigations on sea anemones, especially the common species, Aptaisia, easily found in shallow waters, make an excellent introduction to the study of living corals which are difficult for elementary students to obtain.

BAND 1 primary children can do the suggested observations on anemones both in tidal pools and class tanks. The problem statements contain many challenges for the older BANDS 2 and 3 students. The last three problems take the ablest students into a consideration of tolerance range and behavioral studies.

Appearance.

Sea anemones are beautiful and graceful sea inhabitants. As the group's common name, anemone, implies, these strange and interesting creatures at first glance resemble plants more than animals. Their base (pedal disc) is usually attached to a surface. A thick stalk (column) supports a head region (oral disc) that has tentacles encircling a muscular mouth. The tentacles may be retracted into the oral disc which then contracts inward making the anemone into a round, button shape.



Sea anemones can be many different colors or colorless, bumpy or smooth-skinned, small (less than ½ inch) or rather large (12 inches long). Their column may be free of debris, or may have pieces of shell or sand glued to the skin on surface bumps.

Habitat.

Many sea anemones live within the intertidal zone and are accessible to student groups. Anemones can be found in tide pools, attached to the top or bottom of rocks, on dock pilings, on oyster shells, plants, and even other animals (e.g. hermit crabs), or almost completely buried in sand.

If anemones are in an exposed location during low tide, they are usually at least partially "closed up" (i.e. the tentacles are pulled into the oral disc and the body is contracted). When closed they resemble shiny bumps of jello on the rocks. The anemones will open up again at the next high tide, or in an aquarium.

Collecting.

Sea anemones attached to plants, oyster shells, and small rocks can be brought still attached to their substrates to the class aquarium in a bucket with sea water just covering them. This will probably be the most successful collecting technique.

Other anemones, attached to large rocks or dock pilings may be collected by gently lifting the basal disc with one's fingers or a Q-tip. Using a knife, even a table knife, could easily damage these soft-bodied animals.

Aquarium Maintenance.

For short term, close observation, sea anemones can be kept in a gallon jar with full-strength sea water and good aeration. For maintenance over a longer period, place them in an aquarium. See Section 1 on Aquaria. Food and feeding techniques are included in Problem 2 below.

Anemones usually contain symbiotic algae within their bodies contributing to their health and well-being. Place the aquarium where it will receive at least six hours of daylight, but not direct sunlight, each day. A lamp placed nearby should work, too, if it is not so close as to warm the water.

Signs of a damaged or ill sea anemone: (1) stomach proturding from mouth, and/or (2) ripped, bruised pedal disc which may balloon out. (Note: after an anemone is collected, even as carefully as possible, its pedal disc may balloon out for a while before it re-attaches in the class aquarium. Also a very few species of sea anemone sometimes move by inflating and floating around, or forming an air bubble under the pedal disc.) If the class notices problems with the anemone (or any other animal), it may be decided that the animal has not adapted to the artificial world of an aquarium and it needs to be returned to its natural habitat.

Problem 1. FIELD OBSERVATIONS

BANDS 1, 2, 3

Field observations of sea anemones may be one item on the agenda of a general field trip. Field observations are generally gross but they give the students a "feel" for the natural habitat of the animal.

Problem:

Observe sea anemones in their habitat.

Suggested Procedures.

If a rich sea anemone source is located within easy driving distance of the school, a Short Field Trip (see Section 1) could be planned for the express purpose of observing and collecting anemones.

When planning an Extended Field Trip, check to see if the place to be visited has anemones. If so, include preparation for observing and collecting anemones in the work agenda for the Extended Field Trip.

Select and "translate" whichever questions and suggestions below seem to suit the grade level and ability of the class. The questions can be gone over with the class before going on the field trip, or a general preparation about anemones can be made and the detailed questions saved for discussion on site. (Information in parentheses is for the teacher's use only.)

-Where do you find sea anemones? (usually attached to a hard substrate covered with water, possibly exposed at low tides)

-Does each sea anemone live alone or do anemones live in groups? (both, but usually in clusters in tidal areas)

-What does a sea anemone look like? What color is it? What shape? How big are anemones?

-There are many kinds of sea anemones. Are there different kinds in this area? What differences do you find in size, shape, color, softness, etc?

-Feel a sea anemone. (Members of this phylum are equipped with stinging cells in the tentacles but students are not likely to come in contact with these in touching the closed anemones. Even if they do, anemone stinging cells are not likely to pierce the human skin. Should a nematocyst happen to penetrate a finger, the sting will be hardly noticeable. Other members of the phylum have more toxic nematocysts such as Portuguese Man-o-war.)

-Here are names of parts of a sea anemone. Look for parts which might match these names: TENTACLES, MOUTH, COLUMN, ORAL DISC, PEDAL DISC (Pedal means foot; also called Basal Disc.)

-What does a sea anemone do when you touch it? (recoils)

- Some sea anemones have sand or bits of shell stuck to their columns. If any of your anemones have, can you carefully remove these pieces? How tightly are they stuck on?
- What else lives in the immediate area of the sea anemone?
- What kinds of things are the sea anemones attached to?
- How deep is the water in which your anemones are living? Are they ever exposed to the air?

When it is time to leave the beach and return to school, carefully select a few anemones to bring back to the classroom tank for closer observation. (See Introduction to this topic for methods of collecting sea anemones.)

BAND 1 children complete their work when they observe and discuss what they have seen. BANDS 2 and 3 students can be expected to make notebook reports with diagrams.

Problem 2. CLASSROOM OBSERVATIONS BANDS 1, 2, 3

Problems:

How do sea anemones behave in a classroom tank?

How did sea anemones get their name?

Suggested Procedures.

Place a few sea anemones in each of several gallon jars with aeration and distribute the jars to different locations in the classroom where students can glance at them from time to time between doing their other lessons. Another way is to let the students take turns sitting near the aquarium where the anemones are. Whoever has the seat by the aquarium has the responsibility of logging data on changes in the anemones' shapes and behavior together with a note of the time.

Class tank or gallon jar observations made over a few days' time can be discussed during a science class period.

If the class had no opportunity to observe sea anemones in their natural habitat in the field, some of the questions listed above in Problem 1 need to be taken in class, especially the points about the kinds of anemones and names of body parts.

Students who observed sea anemones in the field can move directly into the questions below, selected and adpated to appropriate grade level.

-What does a sea anemone look like in the aquarium compared to what it looked like when you found it at the beach? Is an aquarium like a high tide? Can you make a low tide in your aquarium? What does a change in tide do to the anemone?

-Some sea anemones move from place to place. Has yours moved? Does it have feet? Can you measure how fast it moves? Can it move up the vertical sides of the aquarium? Can it swim? (Besides gliding, an anemone may also somersault, form an air bubble under its pedal disc and move when the bubble breaks, float upside-down on the water surface, climb using adhesive bumps on its column, or swim with its tentacles. One source says that an anemone can move a little more than 0.5 inches per hour. Another says at most 8-10 cm per hour, noting that an anemone usually moves only when disturbed. It may remain in one spot a long time.) One way of checking anemone movement is to mark the location of the pedal disc on the aquarium with a grease pencil.

-What different shapes does your sea anemone change itself into? Make sketches.

-How many tentacles does your sea anemone have? Do they all have the same number of tentacles? Are the tentacles all the same length and shape? How does an anemone use its tentacles?

-Look up the word anemone in the dictionary or encyclopedia. What is an anemone? (delicate, spring, woodland flower) Do you think sea anemone is an appropriate name for your animal? Can you think of a name you would prefer?

Problem 3. MORE CLASSROOM OBSERVATIONS BANDS 2, 3

Problems:

Is a sea anemone an animal or a plant?

How can you tell?

Suggested Procedures.

Students can be drawn out to suggest different tests by which to discover whether a sea anemone is a plant or animal. They might think of its sensitivity to touch, reproductive methods, food requirements, manner of eating. If the students have already been told earlier that the sea anemone is an animal, they can still carry out various tests to "prove" the point.

The qeustions below can be adapted as needed to prod student ideas during a lag.

-If a sea anemone is an animal, is it like any pet animals you have at home? How or how not?

- -If a sea anemone is a plant, how is it like or different from plants you have growing in your yard at home?
- -Can you think of a way to test sea anemones to see if they are animals or plants?
- -What is one main difference between plants and animals which is easy to test for?

If students recommend locomotion as a criterion of animal behavior, observations on locomotion made in the last problem can be recalled.

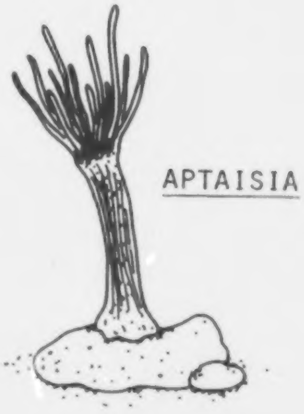
Sensitivity can be tested by noting reactions to touch to different parts of the body, reactions to light, to temperature changes. These latter tests will be elaborated upon in later problems in this topic.

Usually student testing for animality comes down to looking at food requirements and food, a very good criterion, by the way. For tests on food and feeding the class perhaps could use small bits of chopped fish, luncheon meat or canned dogfood as the anemone's food. In their natural habitat anemones eat almost anything, though some prefer living to dead material. Some catch small planktonic animals or fish; others eat larger benthic animals. Some kinds of anemones may initially ingest even inert objects, when really hungry, but will soon accept real food in preference to say filter paper. A large anemone at the Laboratory School ate an entire french fry one day! A flavor test may be devised by soaking filter paper in fish juice, meat juice, other juices, and seeing which is more readily accepted by an anemone.

Place the food near the anemone, or directly on its mouth, perhaps using forceps or chopsticks. The anemone may use tentacles or cilia (small hairs) to move the food into its mouth. The mouth may even reach out to grab the food!

The thin-walled, common sea anemone often cultivated in aquaria are the easiest species on which to observe feeding reactions since their bodies are translucent and the food can be seen inside the animal.

BANDS 2 and 3 students could keep data on how much and how often to feed an anemone. The scientific literature says an anemone is ready to eat when it is in the expanded condition. After taking a certain amount of food, an anemone may appear satiated: its tentacles respond slowly, then not at all to its food.



Upper level students can be expected to report data, discussion and conclusions in notebooks. See PROGRAM MANUAL on reporting styles.

Problem 4. GROWTH OF A SEA ANEMONE BANDS 1, 2, 3

Problems:

Is the sea anemone bigger now than when you first collected it? Has it stretched bigger or has it grown bigger? Is it longer? Is it fatter, or wider?

If you think it is really growing, can you think of a way to measure how much it is growing?

If an anemone establishes itself in the class aquarium, and is being fed at regular intervals, it may begin to show noticeable growth, particularly if it was a small specimen when collected. If the students notice that the anemone seems to be getting bigger, they may initiate a growth study. Students who have had more experience with scientific procedures may have already measured the anemone when it was collected.

Suggested Procedures.

The students may want to take turns making a length (and possibly some diameter -- oral or pedal disc) measurement every day. Daily measurements might be better than weekly ones because small errors can then be averaged out.

It would be best if the measuring were done when the anemone is in a relaxed, expanded state, prior to being fed.

BANDS 2 and 3 could be encouraged to record this information in a bar graph form. (See PROGRAM MANUAL on Graphing Techniques.)

BANDS 2 and 3 may want to investigate the relationships, keeping data, between the amount of food fed the anemone and the resulting increase in length and/or girth.

Problem 5. REPRODUCTION OF SEA ANEMONES BANDS 1, 2, 3

Problem:

How do new little sea anemones appear and grow?

Whether or not this problem can be done depends on how much "cooperation" is given by the sea anemones. If they refuse to reproduce in the class tank, this activity will have to be skipped.

The following teacher background information can serve as a guide for directing student observation and measurements whenever opportunities do occur.

Teacher Background Information.

Anemones may sometimes undergo sexual reproduction. Eggs, or sperm, are formed inside the animal's body and are ejected through the mouth, fertilization taking place in the sea water. The fertilized egg grows into a microscopic juvenile stage having a hairy, oval form. But a detailed study of this microscopic process is not within the reach of most classrooms. However, the release of a "cloud" of eggs or sperm, may happen in the aquarium.

Anemones more often show various methods of asexual reproduction. The students may notice a small bump protruding from the side of an anemone. Over a period of time, this bump will grow into a new anemone, complete with tentacles, and will detach itself from its "mother".

Another method is for a sea anemone to divide itself in half along its length. The oral disc gradually constricts in the middle, finally pinching off to form two "heads". Over perhaps several days, each head pulls away from the other, causing the division to approach the pedal disc, until finally there are two anemones where there was only one before!

The third and most common method of asexual reproduction is a condition where a part of the pedal disc is literally left behind while the anemone glides over a surface. Even if it is an extremely small piece, it will grow into a complete anemone. Often there is a trail of several little anemones marking the path the "mother" took!

ENVIRONMENTAL TOLERANCES (BAND 3)

Introduction and Background.

One question a biologist tries to answer about a living thing is: In what kind of environment does this organism live?

By studying the living thing in relation to its surroundings, the biologist finds out that the organism can "stand" certain temperatures or salinities or association with certain other plants or animals, and that it "cannot stand" others. The conditions in which the organism can survive constitutes its tolerance range.

The tolerance range of an organism helps to explain its geographic distribution. It flourishes best when its environment is at the optimum point of all or most of its ranges of tolerance for temperature, pressure, moisture, type of soil it grows in, conditions of water it lives in, type of food, etc. As conditions near the extremes of its tolerance range the organism becomes stressed. For example, tree ferns flourish in cool, rain forests on the Big Island. When a stump is transplanted to someone's hot, sunny yard in Honolulu it still grows but slowly and smaller and eventually it withers and dies. The warm dry climate exceeds its tolerance range for temperature, moisture, and shade.

Some plants and animals have wide tolerance ranges. They can thrive in a broad spectrum of environments, e.g. cockroaches. Some plants and animals have narrow tolerance ranges. They cannot stand much change. An example is reef building coral. If a reef building coral finds itself in water which is too hot or too cool by even a few degrees, it grows much slower and may altogether fail to reproduce. Corals are also very sensitive to reduced salinity.

Coral growth is of great interest and importance to any tropical Pacific Island. But coral are almost impossible for elementary children to study. They cannot be reached where they grow on the outer edges of the reef nor can they be successfully maintained for study in a classroom tank. Even if they could, their growth and reaction responses are so slow the children would be graduated before significant data had been collected.

A solution to the important study of coral lies with a study of their closely related "cousins", sea anemones which can easily be grown and studied in an elementary laboratory. A look at what conditions are stressful to a sea anemone can give some understanding of the effect of stress on coral polyps.

Studying tolerance ranges and stress in general is becoming increasingly important in pollution studies. We need to know how far we can go in changing or polluting an environment before grave stresses are placed on important organisms in the area, including on ourselves.

Only three tolerance range or stress situations will be considered on anemones in the next three problems: lowered temperature, lowered salinity, and light changes. These three environmental conditions are key factors in the growth of the anemone's close relatives, the corals.

Problem 6. TEMPERATURE TOLERANCE BAND 3

The particular sea anemone used for this study is the common Aptaisia. The students may need some discussion of tolerance ranges and environmental stress before getting into this problem.

Materials.

- *Two (or more) gallon jars with sea water and aeration*
- *Sea anemones established in underwater cages (see diagram below)*
- *Thermometer*
- *Refrigerator or ice cubes for producing cooled water*

Problems:

At what temperatures do sea anemones live?

How does a sea anemone behave or react when it is exposed to a lowered temperature?

Do these reactions seem to indicate stress? How do you know?

Is stress greater or less if the temperature is lowered suddenly or if it is lowered gradually?

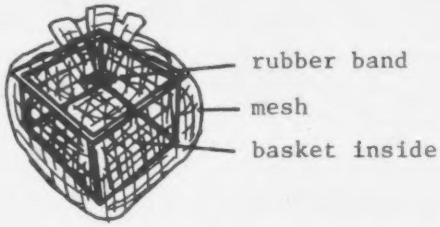
Do anemones recover from stress due to lowered temperature? How long does it take them either to die or to recover?

Compare the stressed anemones with control anemones at ambient temperature.

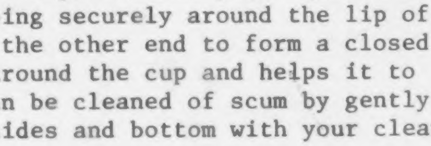
Suggested Procedures.

Go over the questions of Problem 6 with the students and give them time to plan how they might design an experiment to answer the questions. They may need help in understanding and planning for the control. The idea of ambient conditions needs explanation. (See the PROGRAM MANUAL on Controls. If the students are not well versed on controls, stop and do that before going on.)

Build several sea anemone underwater cages. For larger anemones an underwater cage can be made by covering a strawberry or a cherry-tomato basket with coarse mesh nylon which can be easily seen through but fine enough to retain the anemone inside.



For smaller anemones, use transparent plastic cups, making holes for water exchange by punching a (preferably heated) small nail through the sides and bottom. In our experience these cups, even with an anemone in them, float with the rim at the surface of the water, thus making a natural "top" to prevent the anemone from escaping. Once in a while when knocked, they sink, but gently bob to the surface again. If for some reason the cups sink in your aquarium, you might try wrapping a piece of plastic tubing securely around the lip of the cup, sticking one end of the tube inside the other end to form a closed ring. This forms a little "inner tube" around the cup and helps it to float at the surface. These cup-cages can be cleaned of scum by gently pouring out the water and rubbing the insides and bottom with your clean finger, avoiding the anemone.



The students may be able to invent an even better kind of underwater sea anemone cage.

Set up two (or more) gallon jars with sea water and aeration. These will be the test chambers in which temperatures will be varied.

Set up another gallon jar with aeration and sea water which is kept at the same temperature as the holding tank (the ambient temperature). This is the control for purposes of comparison.

Establish two or three anemones in each underwater cage and let them adjust to their cages for a few days in the class aquarium.

It may require several days or longer to complete the tests, allowing time for the sea anemones to rest in the holding tank between tests. The time can be shortened by using more cages and more test jars simultaneously.

Cool the sea water in one of the test jars to be a few degrees cooler than the sea water in the holding tank. Decide how much cooler the test jar should be, for example three degrees, or five degrees.

When all is ready, move one cage of anemones into the cooled sea water and another cage of anemones into the control jar.

Carefully monitor the reactions of all the anemones, particularly how they respond to food. Decide how long you will collect data. When finished, return the sea anemones to the holding tank for a day to recover before testing again, or continue testing with different anemones.

Decide how much further the experiment should continue with decreases of temperature.

Discuss the reactions of the anemones at the different temperatures. Try to account for any unusual behavior. At what behavior reaction did you decide that the anemone was under stress? What were the stress reactions? Do you think you exceeded the anemone's temperature tolerance range? How do you know? How long did it take the anemone to readjust (by stages) to normal tank temperature? How did the control jar help to interpret the reactions of the anemones in the test jar? Draw a conclusion about the lowered temperature tolerance range of sea anemones.

Problem 7. SALINITY TOLERANCE BAND 3

Unlike most anemones, the little smooth-skinned brown sea anemone, Aptaisia, is fairly tolerant of wide ranges in salinity. It seems to be able to live in semi-polluted water and brackish water. Aptaisia can be found in the Ala Wai Canal. Test specimens at the Waikiki Aquarium have been taken down step by step to nearly fresh water.

The general rule in subjecting animals to environmental changes is to do it gradually to prevent "shock" to the animal's physiology. But since

Aptaisia can adjust almost immediately to salinity changes (as when a rain storm inundates a tide pool) the tests below can proceed in fairly drastic steps. In fact the change in salinity may need to be as drastic as 20% or more in one step in order to precipitate stress reactions.

Pre-requisite to this experiment is doing the Sea Water topic given in another part of Section 2. Until the students have made a hydrometer and learned to understand and measure salinity, they cannot do this problem.

Materials.

- *Sea anemones established in underwater cages as in the above problem*
- *Student-made hydrometers (from the Sea Water topic) or a commercial hydrometer*
- *Many gallon jars or plastic bag aquaria as described in Section 1 under Aquaria*
- *Standard sea water (from the Waikiki Aquarium or from offshore)*
- *Tap water with which to dilute the standard sea water to different percentages of salinity*

Problems:

What is the salinity of natural sea water?

What is the salinity of the sea water in the class aquarium?

What is the lowest salinity which sea anemones will tolerate?

What can you conclude from this?

Suggested Procedures.

Review with the students the work done in the Sea Water topic so that they recall what sea water is, what its salt concentrations are, how to make dilutions, and how their hydrometers work.

Challenge the students to design an experiment by which they can test the tolerance of sea anemones to salinity levels less than that of normal sea water. Remind them, if they forget, of the need for controls, data keeping, replications. (See PROGRAM MANUAL on these topics.)

The following procedures and questions provide a "fall-back" in the event that student plans are inadequate.

Establish sea anemones in underwater cages in the holding tank, ready for testing. See Problem 6 above for constructing such underwater cages.

Set up as many small test aquaria (gallon jars or plastic-lined boxes) as are needed. Provide aeration, keep temperatures within limits of toleration. Use one (at least) container for each different salinity to be tested.

How will you make less saline sea water? (add tap water)

Begin to move the cages of sea anemones from the holding tank into the test containers and observe carefully for stress reactions.

Maintain a control of sea anemones in standard sea water for comparison.

Take data. At what salinity levels did the anemones find the water intolerable? How could you tell they found it intolerable?

What conclusions can you make from your experiments? Would you expect this kind of anemone to live in shallow, high tide pools? Why or why not? Would you expect this kind of anemone to live near the mouths of streams? Why or why not?

In several laboratory tests on Aptaisia, "stress" reactions seemed to consist of: stubby tentacles, retracted tentacles, shrunken column, constriction of middle of column, swollen column, closed mouth, sending out of acontia (orange strings signalling distress).

In the laboratory tests, stress reactions occurred immediately and then the anemone adjusted to its normal looking behavior within ten minutes to an hour. When the tolerance range was exceeded the stress reactions increased through several hours.

Problem 8. LIGHT TOLERANCE BAND 3

Materials.

- *Class tank and/or gallon jar aquaria with sea anemones*
- *Dark cloths or cardboard to produce darkness*
- *Fluorescent lamp*

Problems:

Are sea anemones more active in the light or in the dark?

How do sea anemones react to direct sunlight?

Is there a level of lightness or darkness at which sea anemones begin to be or cease to be active?

Suggested Procedures.

See if the students can invent some ways to test the behavior of sea anemones at different levels of lightness and darkness.

Among the things to keep in mind are:

- Give time for the animals to react. Do not expect results immediately after a tank is darkened or given extra light.
- Do not forget controls, replications, and the possible presence of other limiting factors. (See PROGRAM MANUAL under these headings.)
- Giving extra light to a small tank, especially if direct sunlight or an incandescent bulb is used, can rapidly raise temperature, thereby adding in an additional change factor. Can you keep temperatures the same while light levels are altered?
- Students might think of using a camera light meter to measure light intensity. Other ways of measuring might be to use descriptive phrases such as "daylight but not direct sun", "dim light but bright enough to read by", "too dark to read", "pitch black", and similar descriptions.
- Information supplied by the teacher might include that many sea anemones contain symbiotic, chlorophyll-bearing, protists (let them look that up!), or explain that these microscopic guest plants need light in order to photosynthesize and produce food used by the anemone (otherwise the animal itself usually is more active at night).

Closing discussion of the data might include consideration of where and at what depths sea anemones might prefer to live in nature.

BAND 3 students who were able to pursue one or more of these last three sophisticated problems on environmental tolerances can be expected also to have the competence to make creditable written notebook reports. See the PROGRAM MANUAL for reporting styles.

These experiences with anemones will be useful in studying corals in the next topic.

10. CORALS

Although corals are the most important animals of the reef (they are makers of reef), corals are difficult for youngsters to observe. Living corals occupy the outer margins of the Hawaiian reef to where young children cannot get. The living polyps are usually too delicate to survive the rigors of a classroom tank. For these reasons, corals are studied here by comparison with their "cousins" the anemones, as well as by simulation using play dough and by looking at coral skeletons. Pictures, dictionaries, encyclopedias, and the teacher's instructions may need to be relied upon more in this topic than in dealing with animals which can be maintained alive and observed close-up.

The students may generate problems about corals which they would like to pursue. Their preferences may influence the teacher's selection, omission, or modification of the ideas developed here.

Six problems on corals are presented in this topic:

1. The Form of Living Coral (a combination of hard and soft parts shown by play dough models)
2. Coral Vocabulary; Coral Behavior and Reproduction
3. Coral Skeletons (Are they alive or dead? Of what use are they to a coral?)
4. Coral Growth; Kinds of Corals
5. Chemical Composition of Coral Skeletons (application of the vinegar test learned in the sea shell lesson)
6. Coral Heads (their mass, volume, density)
7. Coral Reefs (their types and distributions)

Problem 1. THE FORM OF LIVING CORAL BANDS 1, 2, 3

In lieu of observing live corals, this activity gives the students a tactile experience of what coral polyps may be like based on their previous knowledge of anemones. The Background Information following the Suggested Procedures will help in guiding the activity.

Materials.

-Clay or play dough. See recipes in the Sea Shells lesson.
-Paper baking cups, small size, such as those used for lining muffin tins, or fluted paper candy cups
-Pictures of coral and/or coral skeletons

Activity:

Riddle: What is soft-bodied but stone-hard?

Make a sea anemone from play dough.

Put the anemone in a paper cup (small fluted cup used for muffins or candy).

Let the anemone extend its tentacles to feel the outside environment.

Change the shape of the anemone so that it can hide entirely within the cup.

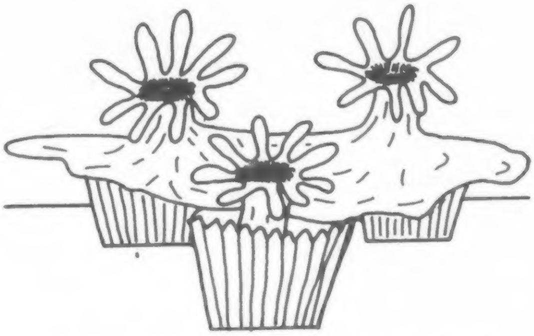
Put many paper cups, each holding its own anemone, next to one another so that the sides of the cups touch.

Connect the anemones in adjacent cups by adding strings of thin sheets of play dough. The connecting dough should reach from each anemone to those on all sides of it.

(The answer to the riddle is the animal represented by the play dough in the paper cups.)

Suggested Procedures.

Make up play dough (or have the students do so) in brown, pink, and yellow, representative of the colors of living corals. Use it to carry out the suggestions given in the box above. Different students might use different colors. When it is time to make the "colonies" by pushing the cups close together, all the yellow anemones could get together, etc. The resulting uniformly-colored and joined-together "coral colonies" are analogous to real corals.



Three interconnected play dough anemones in their fluted cups representing a coral colony.

You might wish to help the students solve the riddle as to what their collection of anemones in cups represent by giving a few hints, such as:

-The fluted edges of the parer cups are, in real life, very hard and white.

-In real life, the "anemones" live in ocean water, not in deep ocean, but not in tide pools either.

-The fluting around the edges of your paper cups represent the lacework in this real specimen. (Hold up an actual coral head, or picture of one, showing the lacy polyp cavities.)

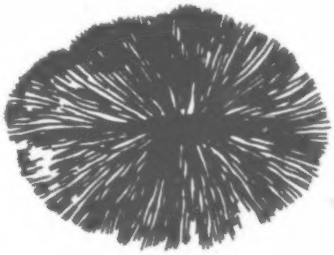
Background Information.

In the last topic (Anemones) it was not apparent at first whether a sea anemone was a plant or an animal. In the case of coral, it may be hard to distinguish it as truly a living thing. When we look at a piece of coral in a museum display case it seems to resemble a crystalline growth in the mineral kingdom. Worn pieces of coral along a beach make us think of rocks.

An entire coral is a living thing; in fact, coral is a cousin of sea anemones. Both corals and anemones begin life as similar juvenile forms (microscopic, many-celled, furry "planulae"), swimming in sea water. When the baby coral settles on a shallow sea floor in a place where it is not too cold or dark, it grows into an anemone-like creature called a "polyp." A young coral polyp takes calcium out of the surrounding sea water, chemically changes it to limestone (calcium carbonate), deposits the limestone underneath and all around its body, and so makes itself a skeleton.

It is the limestone skeleton which most obviously distinguishes corals from sea anemones. It is the coral skeleton that we see in a museum display case; all the once-living soft coral polyps are dead and gone.

Some corals are "solitary", or made up of only one polyp, for example Fungia. In a living specimen the ridges help to support the large, soft-bodied polyp.



FUNGIA
a solitary coral

Most corals are colonial, the original polyp multiplies to form a whole colony of polyps by the reproductive process of budding mentioned previously for anemones. Each polyp occupies its own hole in the large coral skeleton. The polyps are connected to one another by a thin film of living tissue.

Problem 2. CORAL VOCABULARY; CORAL BEHAVIOR AND REPRODUCTION BANDS 2, 3

Corals grow by means of: 1) budding off new polyps from the sides of older polyps, and 2) sexually, by the hatching of eggs into free floating planulae, each of which has the potential to settle on a suitable surface and begin a new colony.

In this activity, the students can make use of the play dough anemones and fluted cups they assembled in the previous problem. The "story" below describes growth behavior of corals. The students can engage in the activity by adding their own comments and by manipulating their play dough to reproduce the described action. At the same time, the teacher can define and use correct terminology as a means of teaching vocabulary.

Vocabulary. (to be woven into the conversation, as needed)

POLYP: An anemone-shaped coral animal.

PLANULA (plural = Planulae): Larval form of coral polyp hatched from an egg.

CORAL SKELETON: A stone-hard, lacy cup in which a polyp lives.

SOLITARY CORAL: A coral polyp which lives in one cup (usually a large one) by itself.

COLONIAL CORAL: Many coral polyps joined together.

CORAL COLONY: Same. (Have students refer to dictionaries. Also recall the joined-together tissues and fluted cups from Problem 1.)

CORAL HEAD: A joined colony of corals.

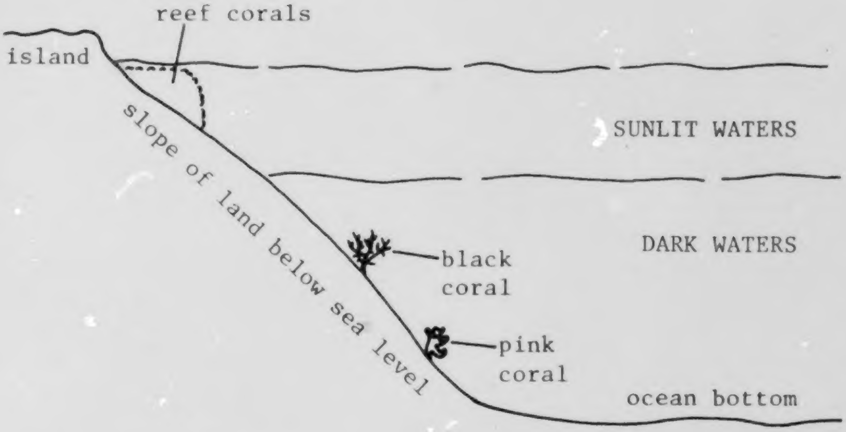
CORAL REEF: Lots of coral heads joined together, added to and reinforced by many sea weeds with stoney skeletons called CORALLINE ALGAE. Many reefs consist of as much or more coralline algae as of coral.

Story Line. (which can be accompanied by comments and play-dough actions by students)

-This coral polyp has some tiny green plants (ALGAE) growing inside its body. The plants need sunshine in order to grow and make food. (Demonstrate by making dots in the play dough coral polyp.) Where should these corals grow? (Near surface waters in light.)

-Some corals do not have green algae living in them. Where can they grow? (anywhere)

-Here is a slope going down from sea level to a deep part of the ocean (indicated by slanted line on blackboard). Where shall we put the corals?



-It's very low tide. Some of the highest corals are almost at the surface of the water. The sun is shining and the water is getting hot. What shall the corals do? (retract to get away from heat, or expand so their included algal bodies can get the sun).

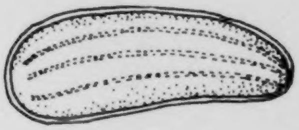
-It's nighttime. Many tiny little plants and animals called PLANKTON are floating deep in the water near the corals. What shall the coral polyps do? (Come out and expand their tentacles to catch a meal. Corals get food: a) by absorbing what their internal algae produce, and b) by ingesting food caught from the water like anemones do.)

-A living coral head is growing near the surface of the water. It is raining very hard. What is happening to the water? (reduced salinity) What shall the corals do? (retract)

-Here comes a big hungry crown-of-thorns starfish. What can the coral polyps do? (retract...get eaten)

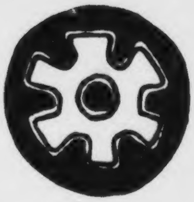
-What can protect the corals from the crown-of-thorns starfish? (Triton trumpet shells eat crown-of-thorns starfish.)

-Here comes a planula carried by a wave. (Hold up a small piece of play dough shaped like a planula.) Where can this little planula go? (Offer a flat surface to which it might attach itself.)



PLANULA

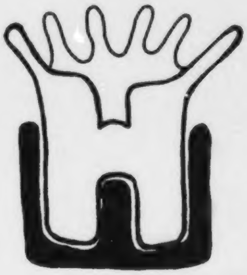
-What do you think will happen to this planula? (Many are eaten. A few will attach to a surface and change into a small round polyp.)



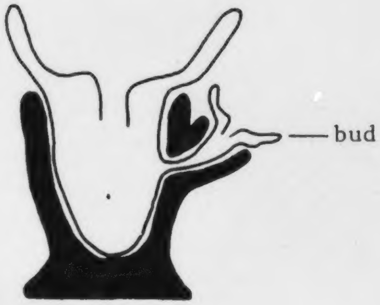
-What shall the new coral polyp do for protection? (Give it a fluted paper cup simulating a newly laid down skeleton.)

Planula settled on surface and growing into a single polyp with beginning skeleton.

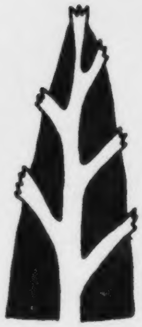
-Some planulae grow up to be single, solitary corals, like this. (Form polyp into single polyp of Fungia type.



-Most planulae grow into a coral COLONY. How can they do that? (Pull a lump out from the side of the polyp and form it into a new polyp imitating the budding process. Add more play dough and continue to bud off more and more polyps. Bring in additional fluted cups for the new polyps until a colony of cups and polyps is formed.)



This story might go on with the students inventing ideas as to what else happens to corals such as growing into a reef, being harvested for jewelry, sending out eggs and sperm to form new planulae, getting broken by waves and storms, tossed up on beaches, collected by children or souvenir hunters, made into paper weights, etc., etc.



Problem 3. CORAL SKELETONS BANDS 2, 3

This problem consists of investigating a coral skeleton to see if it is alive, and finding out of what use the skeleton is to the coral polyp.

Materials.

-*A large coral skeleton in the hands of the teacher and/or*
-*Pieces of beach coral*

Select from, or modify the problem questions as needed according to stoduents' interest or questions.

Problems:

Where are the coral polyps in this specimen?

Whould this piece of coral be kept in sea water? Why or why not?

Should this piece of coral be fed? Why or why not?

Is this coral like a rock? a snail shell? a bone? a tree trunk? a sponge? In what ways does it resemble any of these things?

In the play dough model of coral, what represented this hard white coral?

Can you think of ways this white coral helps the polyps?

Suggested Procedures.

In response to the questions in the problem, the students may suggest that the polyps are retracted inside the holes of the white coral, and that they will expand like an anemone if the coral is put in the aquarium. They may suggest that feeding it will encourage the polyps to expand. Test these ideas and others the students may originate.

After seeing that no polyps expand out of the holes, even when offered something to eat, the students may begin to wonder if they have not got something like a rock! Having a snail shell for comparison may help them begin to think of something leftover after an animal dies. What do we call this leftover part? What is made out of bones inside of us? A skeleton!

The students may think of many ways the coral skeleton helps the polyps. If they get stuck, try these hints for two skeletal functions:

-Have you ever waited a long time for a bus? After a while, does it feel good to lean against a wall? (support)

-To help reinforce the idea that the ridges help support a polyp, you may want to use the analogy of the supports in an umbrella.

-If a fish that eats polyps is swimming toward a coral, what can the polyps do? (retreat for protection)

Problem 4. CORAL GROWTH: KINDS OF CORAL BANDS 1, 2, 3

Corals in Hawaii are at the Northern limit of reef building with a reduced growth rate amounting to as little as a half inch rise in height of the reef per year. A growth rate of this degree is not observable by elementary children. Nevertheless students can investigate the concept of growth rate for coral by analogy to their own growth.

Materials.

- *Samples of corals*
- *Student health records (to find out students' heights for last year)*
- *Yard sticks*
- *Rulers*

Problems:

Can you find out how tall you were last year? How tall are you now? How much have you grown in one year? This is your growth rate for one year.

A coral colony grows too; as it grows older it too grows taller. Its growth rate is from ½ to 2 inches each year. It depends upon what kind of coral it is and how good its environment is for growing.

Can you estimate the age of some of the coral specimens we have here?

Should living corals be collected as readily as one collects flowers, ferns, or nuts? Why, or why not?

Some kinds, or species, of corals grow only in rough water; others grow only in calm water. Then there are some corals that grow in both areas, but look different. They respond to the force of the waves by growing in different ways. These variations are called growth forms.

What kind of a growth form do you think a coral would have if it grew in rough water? What kind of growth form would this kind of coral have if it were growing in calm water?

Can you divide the classroom corals into a "rough water" group and a "calm water" group?

Suggested Procedures.

This lesson could possibly begin by finding the students' growth rate during this past year, using their health records as a data source. Talk about variations in rates from person to person and from year to year with terminal growth for humans in the late teens.

Then the concept of coral growth could be introduced. In the case of corals, growth is by adding new polyps onto old sections of skeleton rather than by our human mode of internal expansion. Also, corals have no terminal age. They may keep growing for centuries until terminated by disaster or environmental deficiency or pressure.

1. Perhaps by comparing the collecting of corals as opposed to the collecting of flowers, etc. the students will see the need for conservation of living corals.

   Students may be able to think of variation in growth form in other things than coral, e.g. trees shaped by the wind. Any other examples? Do people acquire different growth forms because of environmental pressures?

2. Students may have their own adjectives, or even "body language", that may be even more expressive, to describe coral growth forms:

   -In rough water: thick, fat branches; stocky, sturdy appearance; some may be globular.

   -In calm water: thin, delicate branches; graceful, extended, "tall" appearance.

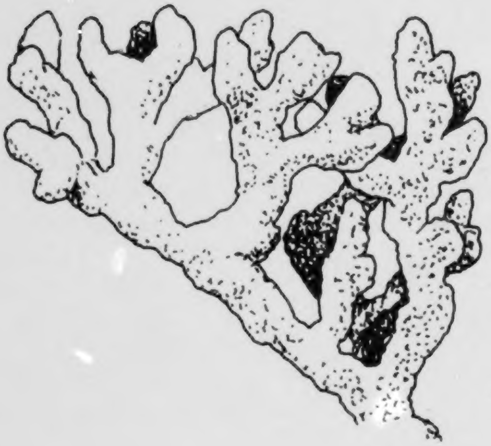
   -Flat-topped table forms often grow near the sea surface.

3. After dividing their corals into the two groups, some students may be interested in trying to find the names of some kinds of coral. This may be difficult in some cases because, as mentioned, growth forms can cause one species to be very changeable from place to place. However, the process of looking for and finding some names is instructive. Some of the common names in particular are very descriptive of the coral's structure, e.g., "staghorn coral" and "brain coral."

Background Information.

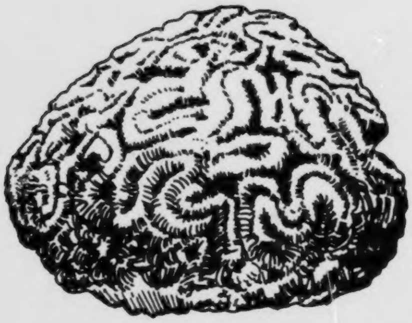
Types of corals which make up the Hawaiian reefs number in the hundreds. The students will enjoy looking at pictures of some of them in books obtained in the library.

Besides the solitary mushroom coral, Fungia, illustrated in Problem 1, a few of the more prominent members of Hawaiian reef corals are shown below.



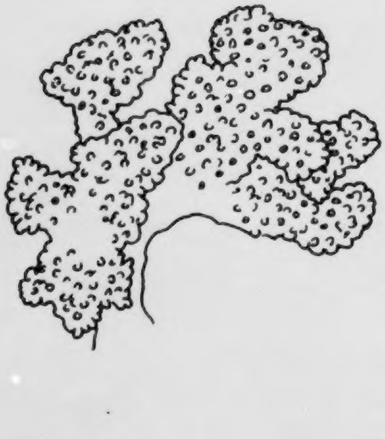
Porites (Po-wríte-eez)

A stoney coral having tiny, closely crowded, pits on massive, rounded formations.



Diploria (brain coral)

Rounded heads indented by serpentine grooves.



Pocillopora. (tree coral)

A finely branched stoney coral.

Problem 5. CHEMICAL COMPOSITION OF CORAL SKELETONS BANDS 2, 3

This investigation considers the nature of a coral skeleton and the source of the mineral material of which it is constituted.

The first two questions in the box below should fall within the ability range of BAND 2 children. The third and fourth questions are more difficult and require a logic which perhaps only the older elementary students can handle. The "chemistry" involved presupposes that the students have completed the sea shell lesson in which they tested the effect of vinegar on calcium carbonate. It also draws upon information learned in the lesson, Sea Water.

Materials.

For questions 1 and 2:

-*Various and sundry skeletons or bits of skeletons to look at*

For the last question:

-*White vinegar*
-*Fine beach sand, Hawaiian type and/or stick of blackboard chalk*
-*Baking soda*
-*Several glass jars of plastic cups for mixing liquids*

Problems:

Is a coral skeleton inside the living coral or outside? What about your skeleton? the snail skeleton? other skeletons?

What kinds of animals have skeletons? Are all skeletons made of the same material? Can you find some skeletons to test?

Do you think coral skeleton is made of the same material as a sea shell? Can you think of a way to test your idea?

Where do you think coral gets the material to make its skeleton?

Suggested Procedures.

In response to questions 1 and 2 the students may have many ideas regarding kinds of animals which have skeletons, what skeletons are made of, and whether they are inside or outside the animal.

Internal skeletons are possessed by vertebrates (fish, frogs, snakes, turtles, birds, and mammals, including dogs, giraffes, and us.) The exceptions are sharks and rays whose skeletons are made entirely of cartilage such as that which gives form to our ears. Turtles, in addition to an internal skeleton, have a shell which is a growth of the animal's backbone and rib cage with a cover of living skin. All these animals have limestone as a small part of their bones. Probably only old, dried bones in which cartilage and blood vessels have completely decomposed will react to the vinegar test.

External skeletons are possessed by arthropods (insects, crustaceans) and many sea animals such as diatoms, sea urchins, sea shells, corals, and others. Some of these are nearly pure limestone, such as the stoney reef corals. Others have limestone as part of a horny-type skeleton somewhat similar to fingernails. Black coral has a skeleton of protein material related to the type which constitutes human hair.

For question 3, the students will need to recall their test made on sea shells using vinegar. Repeating that test here by putting vinegar on a small piece of coral should recall the conclusion that coral is made of the same white chalky stuff which constitutes sea shells and Hawaiian beach sand (calcium carbonate).

Question 4 on where corals get the materials to make their skeletons gives students something to hypothesize about. They may have ideas for tests they would like to carry out or they may wish to refer to encyclopedias. You may wish to perform the following demonstration.

Demonstration of how corals may be able to get solid white calcium carbonate from clear sea water. The rationale for the demonstration goes something like this:

Previous tests (sea shell lesson) have shown that sea shells, blackboard chalk, Hawaiian beach sand, and coral skeletons fizz in vinegar, indicating that all of these objects are probably made of the same type of chemical material (calcium carbonate).

Coral planulae, which are nearly transparent, land on a surface in nearly transparent sea water and gradually build themselves a skeleton of dense solid white stuff (calcium carbonate). Where do these clear transparent corals living in clear water get the solid white stuff for their skeletons, and get it in sufficient quantity to build entire reefs? It seems that they must get it out of the clear sea water. In the lesson on sea water we noted that the oceans contain many mineral salts. Assuming that sea water contains the raw materials out of which calcium carbonate can be made, can the corals get the calcium carbonate out of the water?

We are not going to imitate here the same process by which corals can or might extract calcium carbonate from sea water. What we will demonstrate is that materials for making calcium carbonate can exist as clear liquid from which solid white stuff can be extracted.

Procedures-in-Brief.

1. Mix one cup white vinegar with either two teaspoons fine white Hawaiian beach sand or with one stick of blackboard chalk. Let fizz for one or two hours. Decant and save the clear liquid.

2. In another container, mix one cup tap water with several teaspoons baking soda. Stir from time to time for about 10 or 15 minutes. Let settle until liquid is clear. Decant and save the clear liquid.

3. Combine the two clear liquids. Note the white clouding which will gradually precipitate.

4. Dry the precipitate by evaporation or low oven heat.

5. Test the white precipitate with vinegar to show whether or not it is calcium carbonate.

Procedures-in-Detail.

1. Mix one cup white vinegar with a few teaspoons fine Hawaiian beach sand or with one piece of blackboard chalk. Very fine sand and chalk present much reacting surface area to the vinegar solution. Sufficient reaction occurs in one or two hours to put sufficient calcium ions into solution. Preparation of this solution could be done on a previous day, if desired.

   Pour off and save the clear liquid. The dregs of sand or chalk may be discarded.

   This liuqid represents the clear-looking sea which, like this clear liquid, contains ions which can be reconstituted into white calcium carbonate.

2. In another container, mix one cup tap water and several teaspoons baking soda. Stir from time to time for 10 to 15 minutes. Let settle. Pour off and save the clear liuqid which is a solution of sodium bicarbonate.

3. Combine the two clear liquids. This mixing process represents the coral polyp coming in contact with and reacting with sea water.

   If the mixture does not become cloudy, add more sodium bicarbonate solution until it does. Let stand until the white precipitate settles.

   The white precipitate resting at the bottom of the clear liquid represents the white coral skeleton laid down by the coral polyp.

4. To test whether this precipitate, this "skeleton," is calcium carbonate, pour off and discard the liquid. Dry the precipitate either by evaporation or by oven drying. Test it with vinegar to see if it gives a fizzing reaction typical of calcium carbonate.

In performing this demonstration for the students, you might do only the actions and let them figure out what is happening and what the liquids represent; or

You might explain each step carefully as you go along; or

You might do the show first as a mystery magic show. Let them discuss it. Then do the show again, this time with their own and your explanations inserted at each step; or

You may wish to direct the students to do the demonstration for themselves, working in small groups and later discussing their findings and conclusions.

Problem 6. CORAL HEADS BANDS 2, 3

This problem deals with mass, volume, and density of corals.

Materials.

- *-Coral heads or pieces of coral of different kinds, one per student group*
- *-Pictures of corals to augment the collection of real corals*
- *-At least one solitary coral (e.g. Fungia) in the class*
- *-At least one specimen or picture of a brain coral for the class*
- *-A specimen of coralline algae (a beach pickup showing no poly cavities)*
- *-Measuring and weighing devices*
- *-Squares of kitchen aluminum foil for measuring density*

Problems: (to be selected from and adpated as class need indicates and according to available kinds of coral specimens and pictures)

Examine your piece of coral skeleton. Where would the polyps live if the coral were alive?

Most corals are colonial animals. A few are solitary. Which kind of coral do you have. Which kind do you have pictures of?

Measure the size of your coral specimen. What should you measure to get the size?

Is the biggest coral the one with the greatest volume? What is volume? How can you measure volume?

Is the biggest coral the one which weighs the most? How could you weigh your coral?

Is the biggest coral the one which has the most polyps? Since your coral specimen is dead, how can you count the polyps? (count the holes)

(cont'd on next page)

Problems: (cont'd)

Some corals have a few polyps spread out over lots of space. Other corals have lots of polyps crowded together in a small area, like people living in apartment houses in cities. The amount of crowdedness is called the density. Your teacher will show you how to measure the density of polyps in your coral if you cannot figure out how to do it yourself.

Look at the specimen or picture of a brain coral. How could you measure the number or density of polyps in it?

Some sea weeds have skeletons made of the same hard, white, stoney stuff as corals. They are called coralline algae. How do you think you could tell the difference between a sea weed skeleton (coralline algae) and a real coral skeleton?

Suggested Procedures and Background Information.

One way to start this class is to have the students examine the collection of coral skeletons and pictures. The question of whether they are dealing with one coral, or more than one, is hard to answer. Let the students discuss it. Remind them of their play dough models. There was one polyp per cup. If you put all the cups together, there were many. But with play dough "tissue" connecting all the polyps, where did one individual start, and another end? Is this really neither "one" nor "many"? Look up the meaning of the word colonial.

Fungia is a solitary coral because it has only one large polyp with a mouth in the center and tentacles reaching out along the ridges radiating from the center. Most coral specimens in the class are probably colonial having had interconnecting polyps, one polyp per "hole".

The students may have many ideas on how to measure volume. Some may remember V = length x width x height. Another way that is commonly used when dealing with objects of unusual shape is to get the "displacement volume." Fill a bucket or tub up to the very brim with water. Set it in a pan, then immerse the coral skeleton. The skeleton will displace the same volume of water as its own volume. So, the overflow water is caught and can be measured with a measuring cup, quart jar, etc.

Weight can be determined by using a scale (bathroom, baby, mail).

An easy way to do density is to cut out squares (e.g. one square centimeter or one square inch) of aluminum foil. Press the square onto a partion of the coral to obtain an impression of the polyps. Repeat several times, using different squares on different sections of the coral. Count the number of polyp impressions per square and take the average. Density = the average number of polyps per square unit. BAND 3 students can compute their own averages and compare the densities of different types of corals.

In a brain coral, polyps are located in a meandering "valley." It is as if the mouth of a large polyp had been stretched out along and inside the valley. (Have the students put their fingers inside their mouths and stretch them from side to side.) Furthermore, each polyp mouth joins or fuses with its neighbor's mouth. One scientist describes a brain coral to be "like one continuous polyp with many mouths along the groove." It is impossible to decide how many polyps there are from just seeing the skeleton. Indeed, it would be hard to decide even if we had the living specimen. Although there are separate mouths, the polyp stomachs are in contact; if one mouth gets some food, it ends up being shared by other polyps! The distinction between "one" and "many" is even harder to decide!

Some coralline algae resemble coral skeletons. The fact that there is no place for polyps indicates that the resemblance is superficial. (Refer to Sea Weed lessons for further studies with this plant.) Coralline algae are important constitutents of coral reefs.

BAND 3

Problem 7. CORAL REEF

This problem for upper elementary students draws on conclusions and experience gained from the tolerance range experiments for temperature, salinity, and light done in the anemone lesson, and on student ability to read maps.

Materials.

- *Map of the world, showing coral reef distribution*
- *A simple outline map of your island, one per student (see sample at the end of this topic)*
- *A commercial map of your island showing ocean depths in coastal areas, one per small group of students*
- *Encyclopedias and other references useful in reading about coral reefs*

Activity:

Recall the experiments you did with sea anemones. How did they respond to changes in temperature, salinity, light? Corals are "cousins" to anemones and have similar reactions to environmental changes except that corals are much more sensitive. Corals can stand much less change in temperature, salinity, and light.

Look at maps of the world showing coral reef distribution. Can you explain this distribution?

Use an outline map of your island which shows coastline and rivers. Predict where in your island waters corals might live. Mark these places on the map with dots or small x's or shading.

(cont'd on next page)

Activity: (cont'd)

Where around your island might corals not be able to live?

Regarding temperature, in which places might the waters be too cool? too warm?

Regarding light, in which places might the waters be too dark? too bright?

Regarding salinity, in which places might the waters be too dilute? Look on the map where fresh water streams empty into the ocean. Would this affect growth of a coral reef? How? Why?

Now look at a printed map of your island which indicates offshore depths of water and marks of where the reef is. How do your predictions of where the reef might grow compare with where the commercial map shows that they actually are? Notice where the reefs are wider or narrower. Look for places around the island where there is no reef and where deep water comes close to shore.

If your predictions of where coral could grow match up with where the map shows the reef really is, you know that you have guessed right about the conditions which coral can grow in.

If your predictions of where coral might grow do not agree with the real map, or vice versa, can you explain the difference? If you cannot explain why corals are growing, or not growing, in some places, bear in mind that scientists also sometimes have difficulty explaining why reef does or does not grow in certain spots where they predict it should or should not. Like the scientists, perhaps you can think about some further reasons to try to explain the discrepancy.

From books or an encyclopedia, find out what you can about the following:

Fringing Reefs   Barrier Reefs   Atolls

Which kind do we have in Hawaii?

What else would you like to know about coral reefs? How could you find out?

Suggested Procedures.

Some directions and procedures for this activity are woven into the students' questions in the box above.

The outline map referred to is a simple mimeographed outline of whichever island your school is on. It might be traced from a tourist leaflet map or wherever. It should show a simple outline of the coastline, and lines indicating major rivers and streams. The river outlets to the ocean give a hint of where salinity may drop below the tolerance level of coral. For your convenience, an outline map of Oahu, which you can reproduce, is on an appended page.

A nautical chart (#4110) can be purchased for $4.38 (including tax and handling), from:

Transpacific Company
1406 Colburn Street
Honolulu, Hawaii 96817
Phone: 841-7538

Other sources of commercial shoreline maps are the Atlas of Hawaii, the Marine Atlas of Hawaii, Soil Conservation Service maps, and others you may find in libraires.

Background Information.

Geographic Distribution. Coral reefs have a world-wide distribution; they are located in the Pacific, Indian and Atlantic oceans. However, because of their narrow tolerance range for temperature, salinity, and light, among other factors, they are found in only parts of these oceans.

Limiting Factors. Many factors can influence where coral reefs are found. Reefs are not usually found:

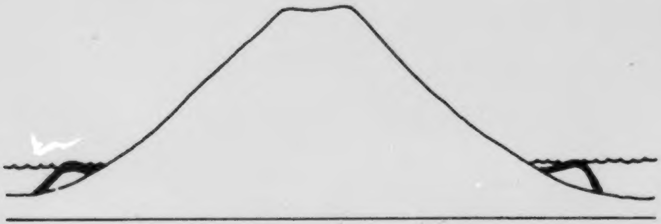
-in sandy bottoms too loose for young coral to settle
-in polluted areas, including mud and silt pollution from soil flowing onto the reef from soil erosion areas
-in continuously muddy waters which obscure sunlight
-in areas of extremely strong currents where polyps cannot settle long enough to take hold
-in areas subject to cold currents which drop temperatures below the tolerance level
-in estuaries and areas extending out from river mouths where salinity is below the tolerance level for corals
-in tide pools which are subject to wide fluctuations in light, temperature, salinity, and cross currents
-in places where the reef has been dredged and the corals have not yet grown back

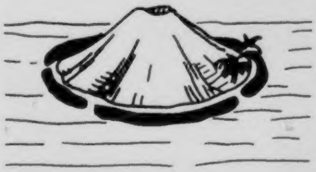
Although some solitary and colonial corals grow in very cold polar waters, reef-building corals are restricted to the area near the equator, growing in water that gets no colder than about 70°F (21°C). Corals cannot tolerate continual exposure to freshwater, so coral reefs are not found across river mouths.

Reef-building corals host small plants within their own tissues (see Sea Anemone problem). Because these plants need light to photosynthesize, reef-building corals do not grow in depths greater than about 100 feet, although the exact depth at any specific location depends on the clarity of the water. On the other hand, corals protect their plant cells from too much light. On bright days in particular, the polyps may be retracted within their coral cups, fully expanding only at night. Black coral, pink coral, and some other forms which do not contain algal bodies may grow at great depths if other conditions are right.

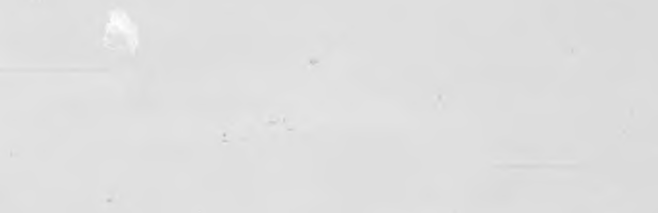
Types of Reefs. There are three types of coral reefs. Understanding how they were formed has been, and is, a complex problem. Charles Darwin proposed a theory suggesting how all three types might be related.

Fringing reefs grow right alonside the coast, often separated from the shore only at high tide. These reefs are found around "young" islands, ones that have been formed "recently" in terms of the age of the world. Hawaii has fringing reefs.

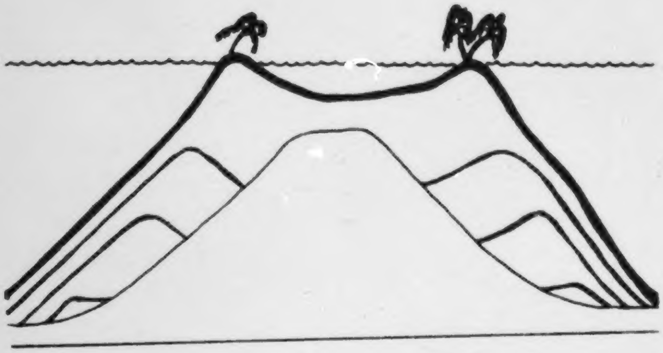


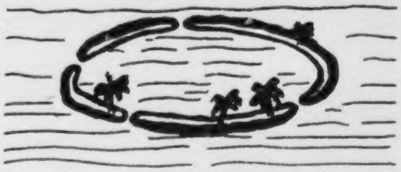


As these islands, and the ocean bottom they are formed on, sink during periodic heaving of the earth's crust, individual corals grow up vertically to maintain the reef at the same level relative to the sea surface. In so doing, they form a *barrier reef*. Eastern Australia has a great barrier reef.



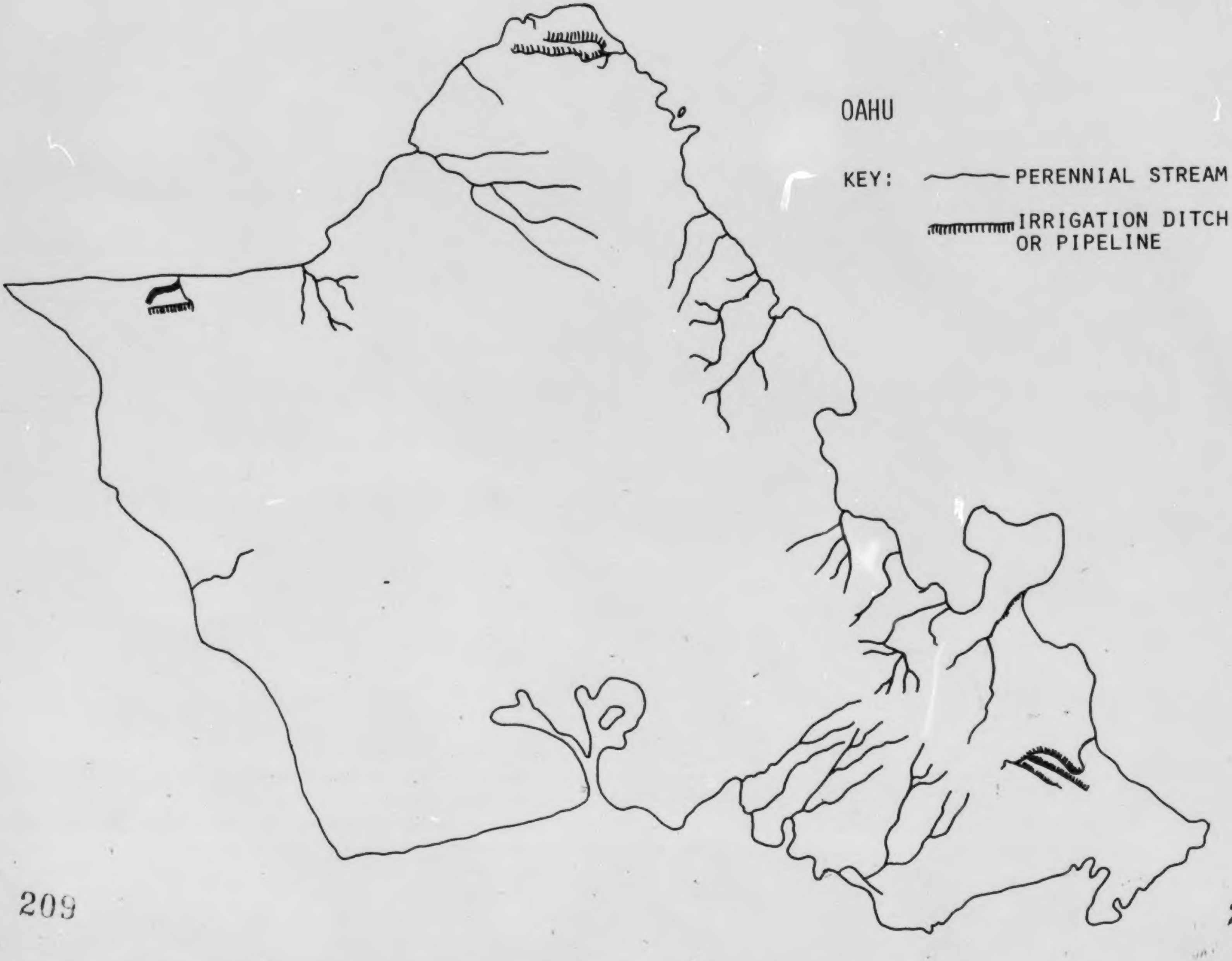
After a very long time, an island may sink below the sea surface, leaving only the coral reef, now called an atoll. Many atolls dot the Pacific Ocean.





As coral colonies grow older, certain types of marine organisms (bivalve mollusks, sponges, even some kinds of algae) bore into the coral surface, producing fine sand. This sand is cemented into the cracks and crannies of the riddled coral skeletons by another group of organisms, the chief one being encrusting red algae. Because of this important role in the formation of coral reefs, some scientists would prefer the term "algal reefs"! In some areas of the reef this term is more accurate. Red algae are the dominant species of the near-surface ridges and subsurface buttresses that meet the ocean waves head on. Thus, coral reefs form bulwarks, or natural jetties, that protect islands from the full force of the ocean.

Living Communities. Coral reefs provide a place for many plants and animals to live. In fact, there are more kinds of living things found in a coral reef than in most other marine communities.


OAHU
KEY:
PERENNIAL STREAM
IRRIGATION DITCH OR PIPELINE

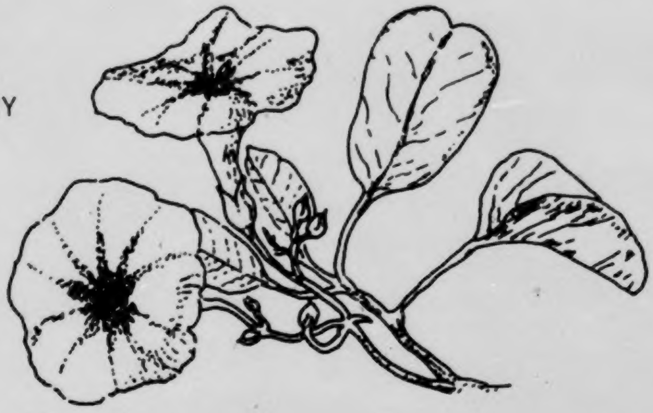
11. SHORELINE LAND PLANTS

Introduction.

Certain land plants flourish along shorelines and these are likely to be encountered by students during field trips to the beach. It is worthwhile to take a moment during a Reef and Shore field trip to have a look at land plants growing nearby.

Coarse grasses, sedges, small weeds, and other salt-resistent plants, face onto some beaches. Rocky beach areas may be devoid of small plants but may have coconut or other trees growing close to the water's edge. Frequently observed in sandy areas are Beach Morning Glory and Naupaka shrubs. A very few of our shores have mangroves reaching into the shallow waters.

BEACH
MORNING GLORY



The following suggested activities and questions must be selected according to whatever vegetation is available for observation. Topics suggested can make for conversation and discussion while walking down a trail to get to a beach or woven into conversation during a break between sessions in the water. The activities and questions are not set up in the customary problem style although they can easily be made into problem statements for data taking and notebook reporting if a teacher so desires.

Phrases in parentheses are intended as teacher information only.

Questions and Activities for Observation of Shoreline Plants.

1. Abundance of Beach Vegetation (percentage of ground cover).

   -How thick or dense or close together is the vegetation from the road where we parked our cars down to the beach?

-Does the vegetation thin out, or get thicker, or change in height, as we approach nearer to the water?

-Does the vegetation occur in patches or is it evenly distributed? If it occurs in patches, can you see any reason why this should be so? (Presence of rocks, shade from trees, trodden pathways, windswept areas, wind-protected areas, wet areas).

-Does any vegetation grow in cracks of rocks or on top of rocks?

-Estimate what percentage of the ground is covered by plants (e.g., if about 3/4 of the ground has plants this is 75% coverage).

2. Location of Vegetation Relative to Shoreline.

-Can we see any vegetation growing in beach sand?

-Look for evidence of the height to which the highest tidal waters reach. This is the High Tide Line or High Tide Mark. How far (meters, feet) is it from the high tide mark to where the vegetation begins?

-Is the distance from the high tide line to the vegetation the same along the entire beach? If it is sometimes closer and sometimes farther what seems to cause this difference? (Presence of rocks, trees, degree of slope or elevation, greater inundation of water in some places, etc.)

-Does any grass or other vegetation grow down far enough to be touched by the highest tide waters?

3. Soil Under and Around Beach Vegetation.

-Look at the sand under the leaves and around the roots of the beach plants. Is the sand under the plants a different color? texture?

-Can you explain why, or why not, it is different? (Fallen leaves and plant parts gradually turn to humus and mix with the sand, giving it a darker color and soil-like texture. In some areas, brisk winds and shifting sands do not permit the accumulation of humus.)

4. Leaf Textures.

-Look at the thickness and surface texture of leaves on beach-growing plants. Compare these leaves with hibiscus leaves, for example, or with leaves of other plants which grow far inland. Do they differ? If so, in what ways, and why? (Beach plants in general have thicker, tougher leaves and rough textures. They must withstand pelting of sand and salt particles.)

5. Trees and Tree Roots.

-Do any coconut trees grow along this beach? If so, which way do their trunks bend? toward the sea, or toward the mountains, or in many directions?

-What other trees grow in the area? (These may include a variety of kinds. Frequently found near shorelines are Ironwood, Algaroba, Pandanus, Sea Grape, False Kamani, Hau. See any book on Island trees for identification.)

-Look for evidence of wind effects on the direction of growth of the tree branches. Look for differences in the heights of trees at different distances from the beach. Can you see any reason for their different sizes? (Wind and water effects).

-Look for trees growing near the waterline. Are they growing on dry ground? Do any of them get splashed by the water at high tide? How can you tell?

-If any trees have exposed roots, why do you think the roots are exposed? Did they grow that way? Did the sand get washed away and leave them exposed? (The latter is nearly always the case except for Mangrove.)

-Do you think it hurts a tree to have exposed roots? (It does, except that such trees usually adapt by using remaining unexposed roots for anchorage and water absorption. If the root system becomes entirely undermined by eroding waves, the tree falls down. The exception is the Mangrove which normally grows in water and produces stilted roots.)

6. Beach Morning Glory.

A very commonly encountered beach plant in Hawaii is Beach Morning Glory which sends out long runners over the sand and puts forth morning glory shaped flowers of a dusty pink color. The buds are pointed and twisted. The closed flowers are turned in upon themselves in a round shape. The two-part capsule contains brown seeds.

-Look along the beach for the Beach Morning Glory vine. Does it have open flowers? What time is it? Is this really a morning glory?

-What color are the flowers? What shape? Among the flowers which are closed, can you tell which are buds not yet opened, and which are old flowers that have closed?

-Can you find any seed capsules? What color and number of seeds are inside?

-Look at the shape of the leaves. The scientific name for beach morning glory is Ipomoea pes-caprae meaning Goat's Foot Morning Glory, named for the shape of the leaves. Do you agree that this is an appropriate name? What shape is a goat's foot?

-Does the vine of morning glory branch or is each vine one single long stem? How long (meters, feet) is the longest stem you can find?

-How is the vine rooted in the sand? Pull up one of the roots, if you can. How long is the root? Is it a single root or branching? Thick or thin?

-Beach morning glory vines were sometimes used in ancient Hawaii for food. Try a piece.

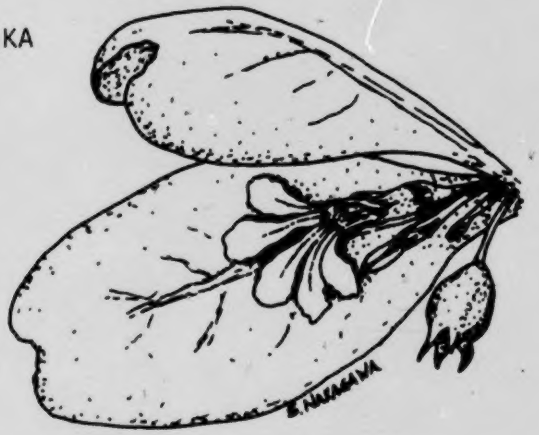
-Beach morning glory vines were sometimes used in ancient Hawaii for cordage. What is cordage? Pull up one long morning glory vine and organize a tug of war to test the strength of the vine. How would you compare its strength with that of other cords of your acquaintance? (The suggestion is to pull up *one* root and do a tug of war with *one* vine. Beach morning glory is sufficiently abundant to allay any fears of exterminating the species. On the other hand, there is no need for a class to tear up a whole beach.)

7. Naupaka.

Naupaka is a broken-hearted maiden forever separated from her lover. She has blossoms which look like half flowers. In the mountains another naupaka grows. He also has a broken heart and a similar half-flower.

(Naupaka, *Scaevola lobelia*, is an exceedingly hardy beach shrub found chiefly on our windward shores. The half flowers are actually entire flowers. If the class has already had a lesson on flower parts, have them examine the flowers minutely to note that each flower possesses all the parts needed for a complete flower, including five petals typical of a dicot plant. The split on one side of the corolla produces an appearance of being a half flower.)

BEACH NAUPAKA



-Look at the naupaka bushes on the beach and see if they seem to be hardy and well-rooted. See if you agree with the textbooks which say that naupaka bushes withstand strong winds, driving sand, scorching sun, that they root themselves in the sand and hold the beach from erosion, growing where little else can be made to grow.

-Examine the fleshy leaves of naupaka. Look for tufts of hair at the base.

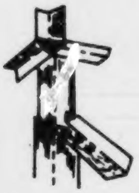
-Look for white fruits. Where on the bush are the white fruits found? What are they like inside?

-There are many different versions of the story about the naupaka flower. All the stories seem to agree that the half-flower of the beach naupaka is a broken-hearted maiden and that the similar half-flower of the mountain naupaka is her broken-hearted lover. One story says the lovers were separated by the jealous goddess Pele. Another story says the maiden herself tore the flower in two, declaring that her lover must bring her a whole flower before she would marry him. He was never able to find the whole flower. She had torn every one in half.

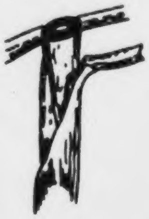
Make up your own story of how the two lovers are represented at the beach and in the mountains by two half-flowers.

8. Beach-side Grasses and Sedges.

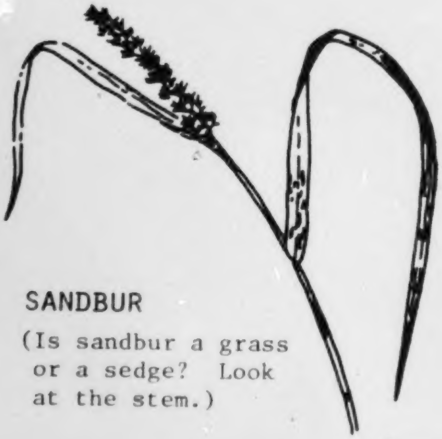
(Most of the tough grasses which grow close to the shoreline are actually sedges, a group closely related to the grasses. The two groups can be distinguished by the shape of the stem. Grasses have round stems, usually hollow. Sedges have angular, usually triangular, stems which are always solid.)



CROSS-SECTION OF
SEDGE STEM

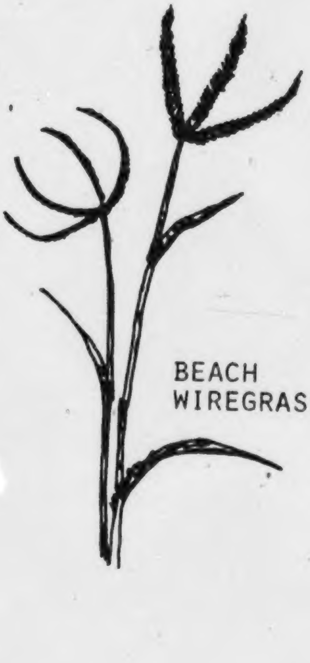


CROSS-SECTION OF
GRASS STEM



SANDBUR

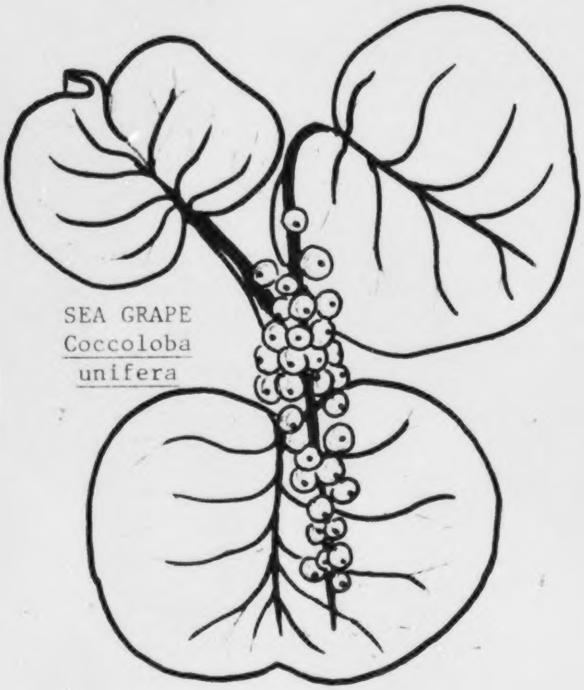
(Is sandbur a grass or a sedge? Look at the stem.)



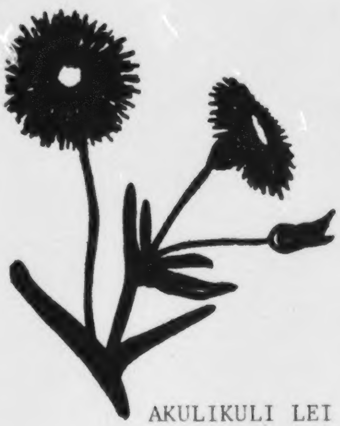
BEACH
WIREGRASS

-Examine the grasses growing close to the shoreline. Are they the same kinds which grow on your lawn at home? Seashore grasses are often much tougher-leaved than lawn grasses. Is that true of those you are looking at?

-Look carefully at the stems. If the stems are round, you are looking at GRASS. If the stems are triangular (or square) and solid, you are looking at a plant called SEDGE.

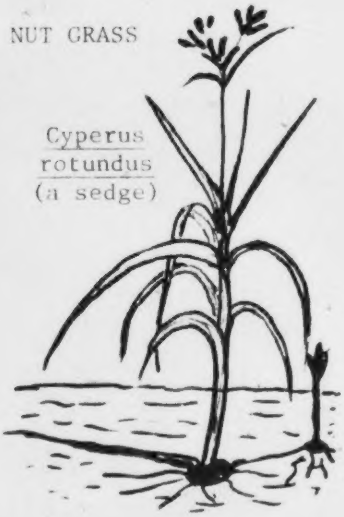


SEA GRAPE
Coccoloba unifera



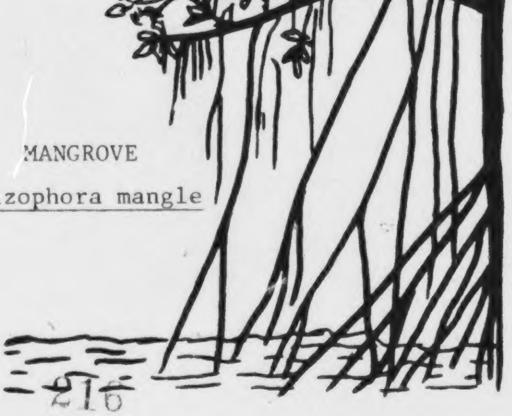
AKULIKULI LEI

Lampranthus glomeratus



NUT GRASS

Cyperus rotundus
(a sedge)



MANGROVE

Rhizophora mangle

12. SEA WEEDS

Introduction.

Algae, or Limu in Hawaiian, are the plants of the world's waters. Algae fill an important niche in the food chain of the sea. They provide a rich nutrient base for animals from zooplankton to man.

BAND 1 children can engage in the observational portions of the problems in this topic. Upper elementary children can do a competent job with sea weed pressing and mounting. Everyone enjoys the eating part!

Problem 1. GENERAL FIELD OBSERVATIONS BANDS 1, 2, 3

Problems:

What shapes, sizes, colors, and kinds of sea weeds grow in tide pools and on reef flats?

Look for those which float and those which are attached. How are some of them attached and to what?

Are they growing in deep water, shallow water, out of water? Do sea weeds grow in clumps? in patches? Are they fairly evenly distributed? Where do they not grow?

Do any animals seem to be making use of sea weed? What use?

Suggested Procedures.

These general field observations of sea weeds can take up a small part of an Extended Field Trip, requiring little more than 10 to 20 minutes of the entire field trip agenda. An alternate idea is to plan a specific field trip devoted entirely to Limu, including observations as in Problems 1 and 2 and sea weed pressing as in Problem 3.

When preparing students for the sea weed portion of a field trip, go over the questions above regarding things for which they should be on the alert.

At the beach, if students need still further help in making observations, you might weave questions similar to the following into the conversation as needed:

-What sea weeds do you find floating? Attached to rocks? To other objects?

-Are sea weeds all over the reef or only in some places?

-Are they completely covered with water? Do some of them stick out of the water? Are any above the water at low tide?

-Feel them. Are they stiff? limp? slippery? (All of these)

-Do they have roots, stems, leaves, flowers, seeds, like land plants? (No)

-What colors are they? (Green, brown, red, other subdued shades)

-What different kinds do you see, for example, stringy kind, thread kind, leafy kind, etc. (See diagrams and descriptions below)

-Can you find any snails or other animals hiding in the folds of sea weeds? (aplysias, anemones, amphipods, many others)

-Do you find any dead sea weeds along the high tide mark on the beach? How are they different from the living sea weeds in the water? (Dried)

-What use, if any, do you think sea weeds are to reef animals? (Food, shelter)

There need be no special report on these observations, except perhaps an oral one, since the pressing and mounting activity below will provide opportunity to make detailed reports.

Problem 2. SEA WEED STRUCTURE BANDS 1, 2, 3

The purpose of this activity is to acquaint students with some of the physical characteristics of a few common sea weeds. This acquaintance serves two purposes: (1) It gives the students a working vocabulary and recognition of the most common local sea weeds. If they get no further than this, the exercise is worthwhile. (2) This base line of information gives a handhold on going into the literature for identification and discussion of further species.

Problem:

What shapes, sizes, and structures do sea weeds have?

Procedures.

Suggestion #1. Plan a special field trip for the class to a shore area rich in limu. At the beach, arrange students in working groups along the shore. Bring pans, notebooks, pencils, diagrams, and have the students in each group examine the sea weeds in their section of ocean. Use the notes below to guide their observations.

Suggestion #2. Gather common sea weeds at a shoreline and bring them back to school in buckets of sea water or in limu bags. In the classroom, float a variety of limu in pans of sea water, one pan to each group of students. Have the students look, feel, taste, smell, and learn what they can about the specimens before them.

The following vocabulary, illustrations, labels, and comments can be used to help the students to examine the most common species of sea weeds collected on most Hawaiian reefs.

Vocabulary for Teacher Usage as Needed.

HOLDFAST: The structure by which a sea weed attaches itself to the substratum. The holdfast looks like a root but it does not absorb water or nourishment for the plant as roots do. Have students compare roots and holdfasts.

SUBSTRATUM: Any rock, coral, shell, or hard surface on which a sea weed (or anything else) can find anchorage.

STIPE: The stem-like part of a sea weed. Stipes, sometimes called stems, do not contain vascular bundles for the flow of sap as land plant stems do.

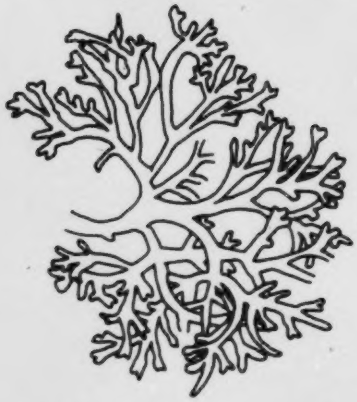
BLADE or THALLUS: Leaf-like flattened portions of the sea weed. Also sometimes called fronds or "leaves".

BLADDER: Small, hollow "balloons" attached to stipe of some sea weeds.

FRUITING BODIES: Rounded or oval knobs, from visible to microscopic in size, which contain the male and female reproductive cells.

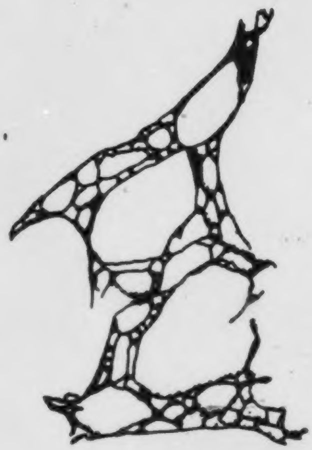
ALGIN: Gelatinous substance in stems and blades which oozes out when the sea weed is pressed. Serves as a glue to keep dried sea weed stuck to mounting paper.

A Few Common Hawaiian Sea Weeds.



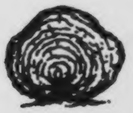
Gracilaria coronopifolia

LIMU MANANEA, OGO - dark rose, greenish; cylindrical branches; grows in small bushes.



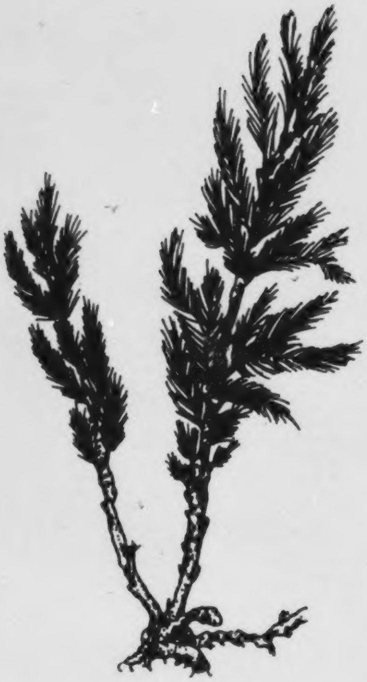
Ulva reticulata

Bright green; looks like a tangle of soft ribbons with holes in the ribbons.



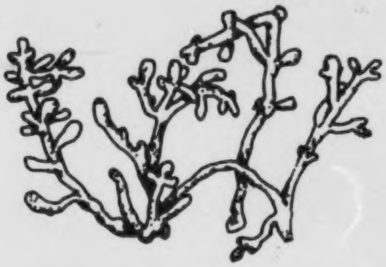
Padina pavonis

Ear-shaped blades with concentric circles in tans and browns; attached to substrate in small bunches.



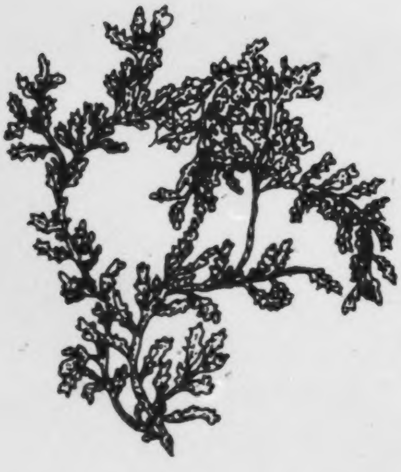
Asparagopsis taxiformis

LIMU KOHU - dark red, brown, tan; holdfast makes strong creeping branches on reef; erect branches (3 to 5 inches tall) have soft fuzzy branches.



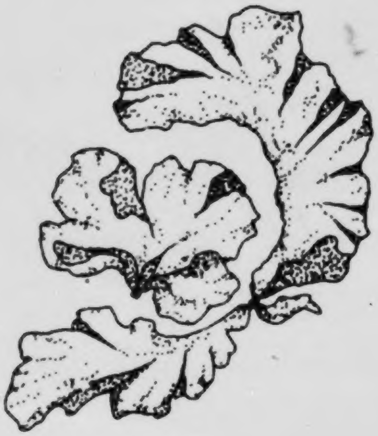
Laurencia nidifica

LIMU MANE'ONE'O - light green with other light colors mixed in; small "bushes" with matted bases; much branched stems 2 to 3 inches tall; peppery flavor.



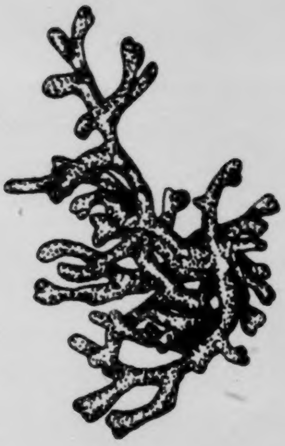
Sargassum echinocarpum

LIMU KALA - golden-brown color, stiff blades like holly leaves with spiney teeth; floating bladders attached to stipe; feels stiff and rough. A species with much larger leaves is common in the Atlantic Ocean. It floats in large bunches near Bermuda making what is called the Sargasso Sea.



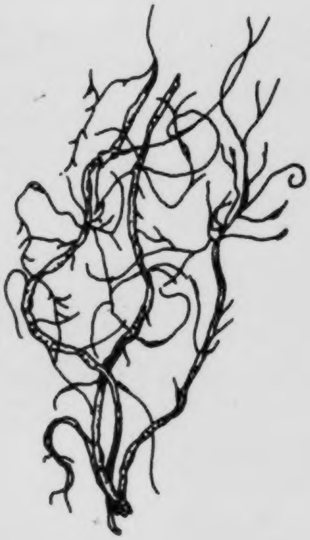
Ulva fasciata

LIMU PALAHALAHA, SEA LETTUCE - bright lettuce green, flattened blades attached in bunches; feels soft and limp.



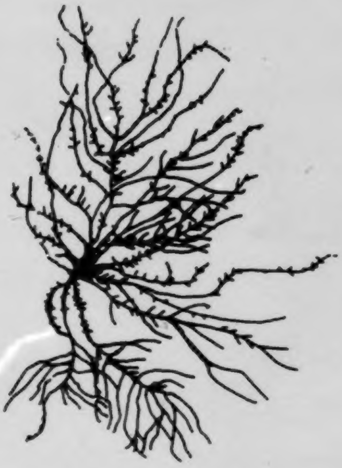
Codium edule

LIMU WAWAE'IOLE - very dark green; forms a mat on the coral; round, branched, tube-like stems.



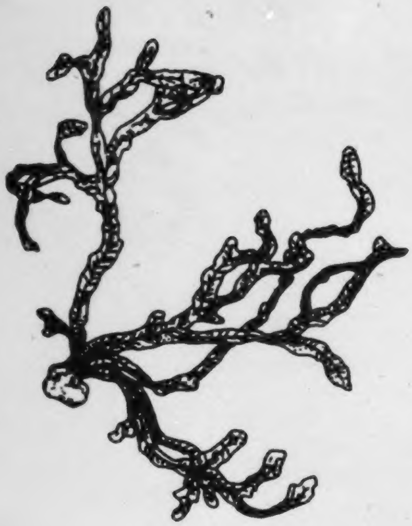
Enteromorpha prolifera

LIMU'ELE'ELE - very dark green, especially after standing; thin, fine filaments, like long hair; firmly attached to substrate; feels slippery.



Grateloupia filicina

LIMU HULUHULUWAENA - dark green, purple, blackish; fine wiry branches, flattened and branched in one plane; feels slippery.



Dictyopteris plagiogramma

LIMU LIPOA, DICTYOTA - wavy, golden-colored blades with prominent brown midrib down the center of the branches; grows in deeper water but is sometimes cast ashore.

Teacher Background Information.

Algae can be grouped by differing criteria. The following are group names frequently encountered.

Diatoms, Bacillarieae: Small, one-celled, free-floating, algae with circular or other shaped hard covers made of silica. Diatoms form an important component of calcareous sands.

Phytoplankton: Small, free-floating algae associated with free-floating, near-microscopic animals. Together they make up the plankton which is the food base of life in the sea.

Blue-Green Algae: Phylum Cyanophyta. Small, bacteria-like, one-celled plants, often chained in filaments. Found on land in damp places as slimy growths. Frequent in fresh water. Also in the oceans.

The larger algae which we usually call sea weeds or limu are classified according to color pigments. The division by color is not clear cut nor always obvious to the naked eye. The "Reds" are sometimes brownish-green because of the mixture of other pigments with the red pigment. The "Browns" are often a greenish-brown or yellowish-brown. Exact classification depends on microscopic and/or chemical analysis.

Green Algae: Phylum Chlorophyta. Usually grass green, e.g. Ulva, Codium, Enteromorpha.

Golden Algae: Phylum Chrysophyta. Usually yellow-green or yellow-brown. Not common in shallow Hawaiian waters.

Brown Algae: Phylum Phaeophyta. Usually brown, e.g. Sargassum, Padina, Dictyota.

Red Algae: Phylum Rhodophyta. Usually dark red, brownish-red, greenish-red, and sometimes hardly red at all, e.g. Laurencia, Gracilaria, Asparagopsis. Included in the Reds are most of the coralline algae whose hard skeletons make a major contribution to the building of coral reefs. The Reds concentrate iodine in commercially recoverable quantities and contain agar used commercially in lotions, puddings, and biological laboratories.

Problem 3. SEA WEED HERBARIUM BANDS 2, 3

Mounting sea weeds is a preamble to their detailed study and classification. Preparing sea weed mounts is a "fun" process which students enjoy. The techniques below are a compilation from the successful experiences and instructions of Ms. Gerry Kajitani and the late Dr. Albert J. Bernatowicz.

Problems:

Learn to mount sea weeds.

Make dry mounts of the kind of sea weeds you find on the Hawaiian reef.

Materials.

- *Holding bag for fresh sea weed (see Procedures-in-Detail for diagrams of holding bag and other materials needed.)*
- *Large flat pan with sea water*
- *Stiff cardboard or other backing to support submerged mounting paper*
- *Mounting paper*
- *Lead pencil*
- *Small, soft, artists brush*
- *Newspaper . . . lots of it*
- *Smooth absorbent cloth rags*
- *Boards and weights*
- *Identification labels*

Procedures-in-Brief.

1. Collect sea weeds from shoreline.

2. Keep in wet holding bag without compacting them.

3. Prepare flat pan of sea water with flat, stiff support in bottom of pan.

4. Obtain mounting paper.

5. Select a sea weed to be mounted. Write name, date, etc. in lead pencil in lower right corner of paper.

6. Place mounting paper in pan on support board. Put sea weed in pan and "float it out." Cut and thin to form a single layer of fronds artistically arranged.

7. Lift the support board slowly and carefully out of the water bringing up the mounted sea weed without disturbing the arrangement.

8. Build a "sea weed sandwich" of newspaper--mounted sea weed--cloth cover --more newspaper--another mounted sea weed--another cloth cover--more newspaper--and so on for many layers. Put a board and weight on top.

   Change the papers and cloths to dry ones after a few hours and daily thereafter until the specimens are completely dry.

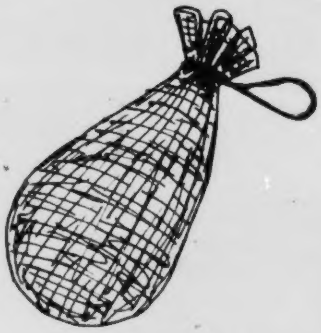
9. Afix a label in the lower right corner.

Procedures-in-Detail.

1. Collect sea weeds desired for mounting. Collect a few sea weeds and collect small pieces. Five or six smallish branches of different kinds per student is enough. Beginning students invariably collect too much and are unable to complete the labor for mounting the large quantities.

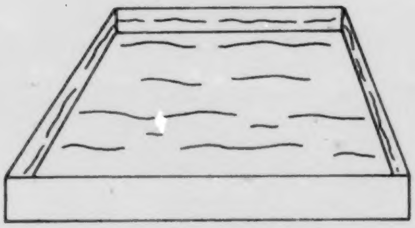
2. Put the collected sea weeds in a holding bag. A holding bag can be a bucket or a plastic bag. Better than either of these is a bag made of coarse cloth. Wet cloth keeps the sea weeds both moist and cool while permitting circulation of air.

   Limu should not be crushed down into the bag but held loosely (as for a tossed salad). It should also not be kept longer than necessary because of onset of wilting and dying.



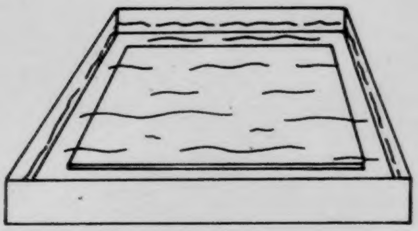
Limu Bag

3. Prepare a flat pan of sea water. This may be done either at the beach or back in the classroom. A sea weed pan is any container with a flat bottom big enough to accommodate a sheet of 8½ x 11 paper with some finger room left all around. The large aluminum disposable roasting pans sold in food markets work well.



Pan of sea water

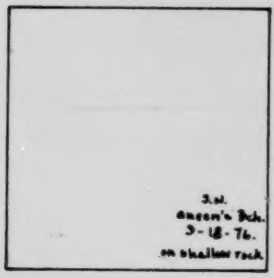
In the bottom of the pan place a flat, stiff support big enough to fit under the 8½ x 11 paper. The support can be a sheet of heavy cardboard which will have to be replaced after each few uses as it becomes water logged. It could be a pane of glass with the edges taped to protect fingers. It could be a thin piece of plyboard. It could be a flat metal sheet.



Flat pan of sea water with support board in bottom.

Instead of using sea water in the pan, tap water can be used. However limu plant cells which are accustomed to salt water tension may rupture in fresh water allowing the plant pigments to spill out. If tap water is used in the pan, work quickly before the color has had time to bleed.

Take from the pack one sheet of dry, clean mounting paper, Mounting paper can be official botany or herbarium paper obtainable at the stationers. Almost as good is mimeograph paper or white construction paper or typing paper which has a fairly absorbent surface rather than a polished glossy coat.



Mounting paper with lower right corner showing student initials, date, place, and sea weed information in lead pencil.

5. Select one sea weed which will occupy the surface area of the mounting paper, or several small sea weeds which will fit on one paper.

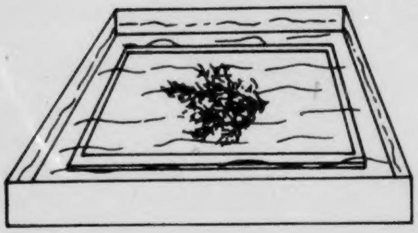
Have the students write their own initials or name in the lower right corner of the paper together with date, place, and information needed to be remembered about the sea weed. This spot will later be covered by a typed label.

(Note: Student names or initials are important. A week later after the mounts are dried no one remembers which sea weed belongs to whom.) Mark the information in lead pencil which does not wash off or stain in sea water.

6. Place the mounting paper in the pan of water on top of the supporting board. Put the selected sea weed into the water and "float it out" into a thin extended position.

Most sea weeds are too full and bunchy to spread out flat. Remove some branches and spread out the remaining fronds with the fingers to be only one layer thick. Arrange the specimen "artistically" so that the shape of each part is visible.

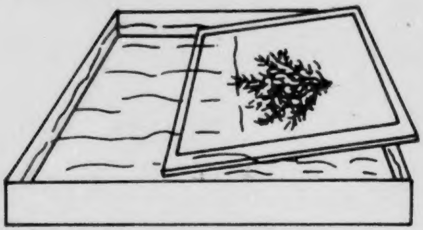
Work in shallow water to keep the limu from floating off the paper.



Support board, mounting paper, and sea weed submerged in pan and covered by ½ inch or two centimeters of sea water.

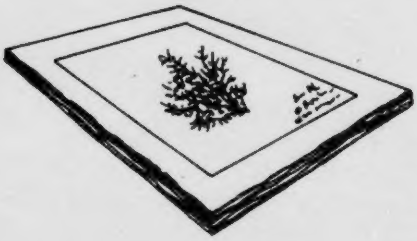
7. Very slowly and carefully, lift the support board out of the water, carrying on it the mounting paper and limu still in the position in which it was arranged. Lift slowly to prevent disarrangement as it is lifted. Drain the paper well. Use the artist's bursh to push out water droplets from between the leaves and arrange fronds in precise position.

   Sea weeds having very stiff branches may be thinned and arranged on mounting paper directly without having to be floated in water.



Support board holding mounting paper and sea weed being carefully lifted out of water.

8. Place a heavy board as a bottom support in a well-ventilated place, or use an old table. On it put old newspaper, about the thickness of one daily issue. On the newspaper place the wet mounted sea weed. Cover this with a CLOTH. It must be cloth. It should also be clean and smooth, without wrinkles. 8½ x 11 squares of old bed sheet work well. (If paper is used, the limu will stick to it and the specimen will be spoiled.)



Wet mounting paper and sea weed placed on several layers of dry newspaper. This will be covered by a dry cloth (not paper towel).

On top of the cloth, place more newspaper about one section of a daily paper.

Then another wet mounted sea weed;

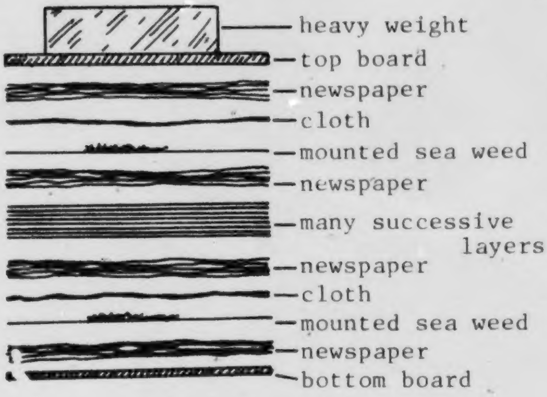
Then another cloth;

More newspaper;

And so on for many layers.

On top of the topmost layer put another heavy board and weigh the whole "sandwich" down with a heavy weight.

Now it is time to clean up spilled water. Toss out or return to the sea unused sea weed, and put away pans and supporting boards for another day.



"Sea Weed Sandwich"

9. Within a few hours or half day after setting up the "sandwich" the newspapers and cloths on both sides of the sea weed are wet and need to be changed.

   Set up another base board beside the first "sandwich." Remove the layers from the original pile, one layer at a time. Transfer each sea weed mount to clean dry newspapers and cover them with clean dry cloths, making a new stack covered by a weight. The wet papers and cloths removed from the original pile can be spread out to dry, ready for the next needed change.

   The second change to dry paper and cloths may come the following day. Thereafter the pile should be restacked with dry paper and cloths once or twice per day until the mounted sea weeds are completely dry.

   How many days are required for complete drying ranges from two days to a week depending upon temperature, humidity, and ventilation in the room.

   The naturally occurring adhesives in sea weed cause the limu to adhere to the mounting paper as it dries. No further gluing is required.

10. Have the students prepare a label to be placed on each mounted page. See sample label below. A number of blank labels can be duplicated and distributed to the students for filling in information and then attaching to each mounted sheet in the lower right corner.

Scientific Name Entomorpha prolifera

Common or Hawaiian Name Limu'ele'ele

Location and Description Paiko Lagoon, near Kuliouou Str.

Special Notes In brackish water. In tufts on rocks at low tide.

Date 5/9/77 Name of Student Mume Ikemori

At first, the line for the name of a sea weed may have to be left blank, but on no account should the students be let off without filling in the rest of the information on each label. The names of the sea weeds can be added as they are discovered by reference to keys or from friends.

Art Lesson.

Well mounted pages of sea weeds collected in a notebook make an impressive display of which both students and teacher can be proud.

The technique for mounting sea weed can be used in an art project by fixing tiny bits of sea weed to the corners of stationary or small calling cards. Combined with matching size envelopes they make elegant note paper, invitations, and thank you cards.

The illustration to the right was printed from an actual mounted specimen. Important to success in these delicate mountings is to drain the paper very well, using the artist's brush to push out all the water from under and around the specimen and arrange the fronds in the desired pattern. For best results, change the dry newspaper and cloths twice each day and use heavy weights in pressing.

Problem 4. SEA WEED RECIPES BANDS 1, 2, 3

This activity involves "having fun eating sea weed." Some edible sea weeds seem better flavored to us and for some we have cultivated a taste. In general, sea weeds make a nutritional addition to the diet and serve as a condiment with fish and other foods.

A good way to introduce sea weed as a food is to select one of the simple recipes below and have the students prepare and eat them. The students might do the preparation themselves, or the teacher may prefer to do the work, bringing the sauces or foods to school as a treat for the students.

Limu Sauces:

Miso Sauce	Vinegar Sauce
¼ cup miso	1 Tbsp. sugar
2 Tbsp. vinegar	½ tsp. salt
2 Tbsp. sugar	½ cup vinegar
½ tsp, MSG	½ tsp. MSG

Limu Treats:

Select an edible sea weed such as Ogo, Codium, or Grateloupia. Wash and clean, removing all sand and foreign particles. Pour boiling water over the cleaned sea weed. Let drain for a few minutes. Add either vinegar sauce or miso sauce. Eat.

Pick only the tenderest young green leaves of Sargassum. Wash and clean well. Gives a spicy flavor eaten with raw fish.

Other recipes can be found in Hawaiian cookbooks. Mr. Ray Rounds of Kailua specializes in sea weed recipes usable with high school and adult classes.

A class mother or auntie who is skilled with sea weed may volunteer or be asked to give the class a lesson on edible limu.

Another idea: Visit a local market and notice the various types of sea weed sold in small plastic containers.

13. SEA WATER

Introduction.

Classroom investigations under this title are intended to bring student attention to the physical characteristics of sea water, with special attention to its salinity.

The first four problems concern the physical properties of sea water as compared with fresh water. The purpose of asking for comparisons is to give the students a base by which to consider the various properties. Elementary children do not yet have the skills, nor the need, for calculating absolute values for density, salinity, and other characteristics. They can, however, obtain notions about these things in relative terms. "Sea water tastes saltier than fresh water", "Things float better in sea water than in tap water", etc.

The last three problems deal with the salinity of sea water. The last two problems for advanced elementary students get into calculations of actual saline content in parts per thousand.

Not all the problems in this topic need be covered. Some are specifically geared to certain levels.

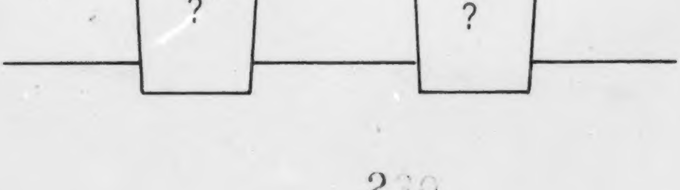
Problem 1. SENSING SEA WATER AND TAP WATER (Primary) BAND 1

This investigation for primary and pre-primary children centers on the characteristics of sea water compared with tap water and brings up points of usefulness and appreciation.

The questions and instructions are written in teacher language and obviously need "translation" to whichever primary level the children require.

Materials.

- *Sea water*
- *Tap water*
- *Peanut butter jars or the equivalent; two jars per small group of students*
- *Newspaper or old cloth for desks or tables*



Problems:

If you have two identical containers, one of sea water and the other of tap water, can you tell by looking which is the sea and which is the tap water?

Can you feel the difference between sea water and tap water?

Can you smell the difference between sea water and tap water?

Can you taste the difference between sea water and tap water?

Health Note:

Regarding the tasting of sea water, any sea water which passes the health requirements for swimming is probably safe enough to dip one small finger in to taste a few drops. Sea water obtained from the Waikiki Aquarium is filtered from many feet down in the reef and is practically sterile of organisms. An added precaution, if desired, is to boil sea water for about ten minutes the day before this class. Let it stand to cool to room temperature or keep it in the refrigerator.

Suggested Procedures.

1. Divide the primary children into groups of three or four children per group. Give two jars to each group, one jar containing sea water and the other tap water.

   Mark the jars with a code so that only you know which is which.

   It may be useful at this time to make an announcement about water being a precious liquid to be kept inside the jars, not spilled on the floor, or sloshed around in the classroom.

2. Before testing for answers to the problem questions and before the students insert their fingers to feel or taste, have them predict whether they think there will be a difference between the two types of water.

   Then proceed with the looking, smelling, feeling, tasting to check on predictions.

   Teach that another name for sea water is salt water. Another name for tap water is fresh water.

   The following questions may be used, as desired, to help along the conversation:

   -Can you tell the difference between sea water and tap water by looking?

-Do you predict that there is a difference in smell? Is there? When you are near the beach does there seem to be a smell to the ocean?

-Do you predict you can tell the difference by feeling? Can you?

-Do you think the two waters might taste different? Do they?

-What do you think causes any differences you found between sea and tap water?

-Where do you think sea water comes from? (ocean)

-Does any one know where tap water comes from? (water pipes, pumping station, rain, ground, etc.)

-Do you like the "feel" of water?

-What do we use fresh water for? (drink, wash, bathe, cook, gardens, swim, navigation on rivers, etc.)

-What do we use sea water for? (swim, aquaria, fishing, ships, etc.)

-What would our world be like if we had no ocean? (no sea shore, no sea animals, etc. More advanced classes might get into oceans as source of rain, weather regulator, ocean industries and resources.)

-Should we take care of our water and of our ocean? Why? How can we take care of water?

-What should we not do to our water and our ocean?

-How can we show our care for the precious water in our two jars? (When finished, pour fresh water onto gardens, lawn, potted plants; sea water into class aquarium or into sink to be returned via sewage outfall to ocean.)

3. BAND 1 ends with oral discussion without notebook reporting.

Problem 2. SENSING SEA WATER AND TAP WATER (Middle Elementary) BAND 2

This is the same as Problem 1 with a few added ideas to give a slight sophistication for post-primary children. The objectives are the same: attention to the existence of, and some characteristics of, sea water versus tap water.

Materials.

-Same as for Problem 1

Problems:

Can you tell the difference between sea water and tap water by looking? by smelling? by feeling? by tasting?

Can you hear through water? How does hearing through water compare with hearing through air? How could you test this?

Suggested Procedures.

1. Procedures and questions for discussion suggested for Problem 1 can be used here with some adjustment in language to suit the older age level. Also, BAND 2 students should be able to keep written data and notes (see sample data sheet below).

2. The data table for this problem can provide good practice for students in designing a data table by themselves, or with some help. See the PROGRAM MANUAL on instructions for making data tables.

   Whatever data table the students design, as long as it is valid, should be used in preference to the following which is supplied as a fall-back.

TABLE 1. DIFFERENCES BETWEEN SALT WATER AND FRESH WATER

Characteristic Tested For	Predicted Differences Between Salt and Fresh Water	Tested Differences Between Salt and Fresh Water
Appearance (looks)		
Smell		
Feeling		
Taste		

TABLE 2. HEARING THROUGH SEA WATER AND TAP WATER

+ means sound is heard better

- means sound is heard not as well

Test Made	Sea Water	Tap Water
Tapping on side of jar with ear pressed to jar		
Tapping on side of jar with ear away from jar		
Ear pressed to side of aquarium near aquarium pump		
Ear near aquarium pump but not in touch with pump or aquarium		
Etc.		

3. Draw some conclusions, appropriate to grade level, about the various test results and what they indicate about the properties of water. The tests on sound might lead into further discussion about sound transmission, fish communication, and sonar.

   BANDS 2 and 3 students can be expected to design and/or fill in data tables and make notebook reports. See PROGRAM MANUAL on report formats.

Teacher Background Information.

Sound transmission is considerably better through sea water, tap water, other liquids, and solid materials than through air. We air dwellers are accustomed to depending on visual communication more than on auditory sounds since light penetrates air rapidly while sound moves relatively slowly. In water the reverse is true. Light is soon damped out but sound carries well and far. Fish can communicate by sounds and at times become "noisy." Man uses sound transmission in water for SONAR and the scanning of ocean floor contours by echo location and depth soundings. Students who become interested in these topics may find explanations in an encyclopedia and other references.

Problem 3. FREEZING OF SEA WATER AND TAP WATER BANDS 2, 3

Introduction.

If a refrigerator is not available at school, this problem may become a homework challenge.

Finding the actual freezing point of salt water (about 3.5°C, lower than tap water) is too difficult for elementary school facilities and student skills. Since the temperature of ice may continue to drop after freezing, the actual freezing point cannot be determined by taking the temperature of the already frozen ice. However the students can see a comparison between the freezing temperatures of sea and fresh water by noting that it takes longer to freeze sea water than tap water. Another indicator of difference is that the refrigerator thermostat needs to be turned to a lower number in order to freeze sea water.

Materials.

- *Sea water*
- *Tap water*
- *Freezer*
- *Ice trays*

Problem:

Compare the freezing of sea water and tap water.

Suggested Procedures.

The students may have ideas about how to attack this problem. If not, the following might be tried:

1. Use a plastic ice tray in which each compartment is completely separate so that water cannot flow from one cube to another, or use two trays.

   Put sea water in one row of cube compartments, filling each cube compartment to a different level: some full, some partly full, some slightly filled.

   Put different amounts of tap water in a similar row of cube compartments.

   Place tray in freezing compartment. Note the "number" or temperature at which the freezer is set. Note the time.

   Check about every half hour to see how freezing is progressing in the cubes of different sizes.

2. Students may design their own data table, or use the following:

TABLE 4. COMPARISON OF FREEZING OF SEA AND TAP WATER

Temperature Setting of Refrigerator __________ Type of Freezer __________

Time	Sea Water	Tap Water
8:00 am	Sea water put into freezer	Tap water put into freezer
8:30 am	No freezing	Slight icing in shallow cubes
9:00 am	No freezing	All cubes iced over top
9:30 am		
etc.	etc.	etc.

3. If each student keeps his own data table, comparisons can be made between times required for freezing, types of refrigerators, temperature settings of refrigerators, etc.

   Several trials need to be made. See PROGRAM MANUAL on Replications.

4. What are the student conclusions about the freezing of salt water compared with tap water?

Do the students have any experience about the freezing of popsicles or ice cream? If not, they might try these. Compare these with the freezing of salt and fresh water.

5. For the format of student reports see the PROGRAM MANUAL.

Problem 4. BUOYANCY OF SEA WATER AND TAP WATER BANDS 2, 3

Introduction.

Children having happy childhood memories of rubber ducks floating in the bathtub and paper sail boats on the swimming pool may continue to indulge their enjoyment and curiosity here, with the added scientific aspect of making predictions and doing tests on floating and sinking objects.

Materials.

-Sea water in a pan
-Tap water in a pan
-Miscellaneous small objects, some denser and some less dense than water

Problem:

Compare floating and sinking of objects in sea water and tap water.

Suggested Procedures.

1. The problem might be introduced by asking the students whether a soap bar floats or sinks in the bathtub, and why. What else floats or sinks? Will these objects float or sink the same way in sea water and in tap water? Stir up as many student questions and opinions as possible, while giving no answers. Answers are obtained by collecting as many objects as possible and trying them out for their ability to stay afloat in both salt and fresh water.

2. Allow some time for the students to collect numerous objects from their own desks at school or at home. Objects may include such items as wooden pencils, paper clips, corks, pieces of wood, soap, paper, plastic ruler, pins, plastic lids, sponge, etc. Have them sort their objects into two piles:

   (1) Objects they predict will float.

   (2) Objects they predict will sink.

3. Give each small group of students two pans or jars, one of sea water and the other of tap water in which to test their predictions.

4. It is advantageous to work with a data table at hand, preferably of the students' own devising or, if necessary, copied from below.

TABLE 5. BUOYANCY OF SEA WATER AND FRESH WATER

NAME OF OBJECT	SEA WATER		TAP WATER	
	Prediction	Actual	Prediction	Actual

Entries in the columns may include such remarks as "floats", "barely floats", "sinks", "floats higher than in salt water", etc.

5. From the evidence collected above, draw together a student conclusion about the buoyancy of sea water versus tap water. Hopefully, their observations were sufficiently careful so that they have noted that salt water holds objects higher out of the water. The conclusion might be stated conversely that objects sink deeper in fresh water.

6. After this conclusion is reached, inventive students might be challenged by the following additional problem.

Problem 5. HYDROMETERS BAND 3

This problem challenges the students to make a technical invention, a hydrometer, based on their previous investigation on buoyancy of sea and fresh water.

Problems:

Can you invent a "buoy" which will show different levels of floating in salt water and fresh water?

Can you use your invention to test the salinity or freshness of different salt and fresh water mixtures?

an incorrect reading.

Tell the students they have invented a hydrometer. They may see a commercial hydrometer in a pet shop or perhaps you have one in your classroom.

The second question of Problem 5 asks the students to make a practical application of their invention.

A hydrometer, either commercial or the one the students made, placed in a container of salt water, will float at the level marked for salt water. If the container holds tap water, the hydrometer will sink to the mark for fresh water. If the water is less salty than sea water, the hydrometer will float somewhere between the two marks. How will it float if the water is more salty than sea water?

If the students understand how their invention works, they should be able to figure out a use for it also. For starters, consider the class marine aquarium and the fluid in a car battery.

Perhaps it is time to have a short "vacation" from writing notebook reports. Instead there could be a display of hydrometer inventions with an explanation by the young inventors of how each particular hydrometer works and what it might be used for.

Problem 6. THE SALT CONTENT OF SEA WATER BANDS 1, 2, 3

The evaporation process for BAND 1 children can be simply a look-see experience. Older students can be involved in experimental work.

Materials.

-Sea water
-Flat pans (pie tins or equivalent)
-Hand lenses
-Heat source (optional)
-Very fine mesh screen or cloth (optional)

Problem:

Remove salt from sea water and examine the salt.

Suggested Procedures.

1. Student prediction and trials.

Ask the class how it might be possible to get the salt out of sea water. If the class concurs that filtering through a fine screen or cloth should work, support this "excellent idea" and put them to work on it.

The time "wasted" on this futile task pays dividends later when discussing the characteristics of solutions.

If no one thinks of trying to filter dissolved salt through a fine mesh you might make the suggestion yourself, or you may prefer to skip this "filtering" idea and go directly into evaporation.

If the class or a small group of students comes up with other ideas, good or bad, for extracting salt, try their ideas as far as possible.

2. Evaporation.

Hopefully someone will eventually think of evaporation as a means of recovering the salt. A hint may be necessary such as, "I wonder what happens to dirty water left on streets and sidewalks after a rain." The class response that at least some of it evaporates might be rejoined with, "Does the dirt evaporate, too?" Since salt in sea water is invisible some students may think it is not possible to evaporate water leaving the salt behind. The only scientific response to this doubt is to try it out.

3. Set up some salt water evaporating pans.

Method I: Student ideas on how to evaporate. The student plan is the preferred method.

Method II: Put about a half inch or less of sea water in flat pie tins or the equivalent. Let stand for one or two days to permit evaporation at room temperature.

Method III: Gently heat pans of sea water over hot plates or on a stove until evaporation is complete.

Does it matter whether the water is slightly heated or brought to an active boil? Try both, and see.

4. Examine the residue salt crystals with hand lenses. Note shapes, sizes, taste, color, feel of the crystals.

Ask the students to predict whether or not these crystals could be redissolved into water. Redissolve them and note their "disappearance."

5. BAND 2 and 3 students can report in their notebooks on the recovery, appearance, and characteristics of salt crystals. See PROGRAM MANUAL for report format.

Problem 7. THE QUANTITY OF SALT IN SEA WATER BAND 3

In addition to information obtained about sea water, this problem can also serve as a stepping stone into an arithmetic lesson on proportions and percentages, and lead to a discussion or reading lesson about the qualities of different seas of the world.

Materials.

- *Sea water*
- *Evaporating pans (as in Problem 6)*
- *Measuring device (balance or graduated container)*

Problem:

What quantity of salt is in sea water?

Suggested Procedure.

1. Recall the method of evaporating sea water to obtain salt (Problem 6). Ask the students how they could measure the quantity of salt per given quantity of sea water.

   If the students have ideas, use their procedures until they come to a point where they need to be "rescued." The following assistance may be needed.

2. Measure a quantity of sea water into an evaporating pan. Use a quantity which will simplify calculations. If possible use one liter, or at least an easily calculated part of a liter.

3. Evaporate to dryness by any of [illegible] methods used in Problem 6.

4. Measure the dry salt residue.

   Method I: Measure by Volume. Put the salt into a graduated cylinder or measuring spoon and take the reading in ml or teaspoons of salt. This is sufficient for in-class comparisons.

   Method II: Measure by Mass. Weigh the salt in grams on a balance. Text book standards are done by mass so choosing Method II will allow comparison with the standards.

5. Calculate the proportion of salt in sea water.

   Method I: By Volume, i.e., volume of salt in a volume of water.

   $$\frac{\text{ml or teaspoons of salt}}{\text{liters of water}} = \underline{\qquad} \text{ ml or teaspoons of salt per liter}$$

   This can be considered the "class standard" for sea water.

   Method II: By Mass, i.e. grams of salt in grams of water. Can the students determine the mass of one liter (1000 ml) of fresh water? If they weigh correctly, they will find something close to 1000 grams per 1000 ml. This is precise only for distilled water at $4^{\circ}C$ but the discrepancy is not significant at this elementary level. Have the students round off their figures to this number. Then:

$$\frac{\text{grams of salt obtained}}{\text{liters of water used}} = \_\_\_\_\_ \text{ grams of salt per 1000 grams (liter) of sea water}$$

According to standard calculations, sea water contains 35 grams of salt per 1000 grams of water. This is expressed as:

35 parts per 1000, or
3.5 parts per 100, or
3.5% salinity.

6. Compare student results among tests made by various groups in the class and/or compare class results with the standard of 3.5% salinity.

   This gives opportunity to discuss reasons for discrepancies between the class results and the standards.

   a. Does the class agree that it measured "standard" sea water? What is standard sea water? Is all sea water alike? How about sea water from offshore after a rain, or sea water near a river mouth? Does rain on the ocean make a difference to the salinity on the ocean surface? Where did the sea water used in these tests come from?

   b. Are the students willing to stand by their calculations? How many measurements (replications) did they make? See PROGRAM MANUAL in the section on Replications.

      Was there possibility of human error, such as spillage of salt or water during the measuring process, or mis-reading of amounts?

7. Students sufficiently competent to do the calculations in this problem are certainly old enough to do a reputable science report in their notebooks. See the PROGRAM MANUAL on report writing.

Teacher Background Information.

Not all sea water has a salinity of precisely 3.5% although the figure varies but slightly in the open oceans of the world. Sea water collected near shore may be less saline because of run-off of fresh waters from the land, particularly after rains. The same applies to surface waters during heavy rains and to ocean water near the deltas of rivers.

Sea water used for setting standards is taken from the North Sea. North Atlantic and polar waters are slightly less saline than the Pacific, particularly the tropical Pacific. Arctic surface water may be as low as 3.3%. Measurements in the Persian Gulf to as high as 4.0%. Pockets of exceedingly saline water have recently been discovered at depths in the Red Sea. Students may wish to look up the salinity of the Great Salt Lake in Utah, or the Dead Sea.

(Footnote: The boiling points of sea water and fresh water differ by less than half of one degree centigrade. This is not sufficient to test with elementary school thermometers. Hence the test by differences of boiling points is omitted in this series.)

Problem 8. SEA WATER VERSUS TABLE-SALT WATER BAND 3

Introduction.

During the first six problems of this topic, the students examined sea water in comparison with tap water and discovered that sea water had considerable salt in it which to elementary students means table salt. They know no other kind. In this problem we turn the analysis around to see if putting salt and water back together again will produce sea water.

The basis for deciding whether or not table salt + water = sea water consists in testing the characteristics of the mixture to see if it matches the qualities previously noted for sea water. Do the students agree to this logic?

Salt water constituted from table salt is not sea water. Sea water additionally contains trace elements. Since the trace elements are beyond the capabilities of elementary students to detect or test for, the students will be deceived by their gross observations into making a false conclusion that sea water and table-salt water are equivalencies.

Allowing the students to walk a primrose path to a fallacy has its merits. Many a scientific "law" supported by all the evidence of its era has been reversed by later evidence produced by a more advanced technology. The students may as well learn at a tender age that science is a search, not a set of "proofs" or "answers," and that the search is all to often handicapped and limited by honest human error and unavoidable ignorance.

Materials.

- *Sea Water*
- *Tap water*
- *Table salt*
- *Sea salt from the Problem 6 evaporation (for comparison)*
- *The student-made hydrometer*
- *Evaporating pans and equipment as in Problem 6*

Problems:

Can you make sea water by mixing tap water and table salt?

If so, how? If not, why not?

How can you tell whether or not your table-salt water is like sea water?

Procedures-in-Brief.

1. Set up a rationale for the experiment.
2. Plan the testing procedures with the students.
3. Prepare data tables.
4. Do the tests.
5. Have the students interpret the tests and draw a conclusion about the comparison of sea water with table-salt water.
6. Consider sources of error and possible inadequacy of the class testing.
7. Report the final conclusions in the notebook.

Suggested Procedures-in-Detail.

1. Set up a rationale with the students for doing an experiment on the stated problem.

   You might begin by getting student opinion on the first problem question: Can you make sea water by mixing tap water and table salt?

   Hopefully, the class will be divided in opinion. This sets the stage for trying out both points of view to see who is "right." But even if everyone in the class agrees that it can (or cannot) be done, the teacher's parry is still the same, namely to ask, "How can you demonstrate that you can (or cannot) make sea water from tap water plus table salt?

   Some questions useful in guiding the planning might be:

   - If you do mix table salt with tap water, how will you know whether or not your product is the same as sea water?
   - Is there a way we can test for sea water using equipment available in this room? (Scientists usually have to work with available equipment.) Substances are usually considered alike or at least equivalent if they have the same characteristics. So if the mixture to be made by the students turns out to look like sea water, taste like sea water, smell like sea water, freeze like sea water, float our home-made hydrometer like sea water, then it would seem to be sea water, or the equivalent thereof.

   Some students may come up with the idea of using sea salt obtained from the evaporation of sea water instead of table salt as the starting salt mixture. If so, add this idea for making an additional mixture to see if sea water is obtained.

If some students want to compare still further liquids such as distilled water, sugar water, or whatever, add these to the test plans also.

Keep working at the discussion until the students come to a decision that the next valid step is to mix the stuff and test its characteristics to see if it looks, tastes, and acts like sea water.

2. Plan the testing procedures.

Plan with the students how much table salt should be mixed with how much water. Refer to quantities determined in Problem 7.

Also plan who in the class will make which mixtures and who will test for what.

3. Prepare a data table for recording results of the tests. The students should design the data table, even if it takes them some time to do it. If they are unable to do so, use the table below.

TABLE 6. COMPARISON OF VARIOUS SALT SOLUTIONS AND TAP WATER

Tests Made	Table-salt Water	Sea Water	Tap Water
Appearance			
Smell			
Freezing			
Buoyancy			
etc.			

4. Do the tests.

Include all the factors learned in the previous problems. Look, feel, smell, taste, freezing, surface tension, density (hydrometer), appearance of crystals, amount of crystals, plus any other tests desired.

5. Interpret the tests and draw a conclusion.

At the level of refinement possible in an elementary set-up, the table-salt water (if made in the proportion of 35 g of salt per liter of water), will match the sea water in every visible gross characteristic. Thus the conclusion, from the level of testing possible here, can legitimately be that table-salt water and sea water are equivalent.

This conclusion, together with reasons and test results should carefully be recorded in the notebook report.

6. Consider possible sources of error.

First of all, have we made any human errors such as mis-measurements, evaporating under different conditions, using different temperature refrigerators, doing insufficient replications?

Secondly, consider the possibility that there are still other tests or still other contents in sea water which we have not accounted for. For example, on the side of the salt box it says "iodized" or "non-iodized". What is iodized salt? Is sea water iodized? How can we tell, or can we, since we do not have an elementary class test for iodine?

On the side of the brine shrimp egg bottle where it gives directions about hatching brine shrimp it says not to use iodized salt. This would seem to indicate that brine shrimp do not tolerate iodine. Since brine shrimp can live in sea water, does this mean there is no iodine in sea water? Are there perhaps other things besides iodine in, or not in, sea water?

We see here that the problem has gotten too big for us. We do not have the skills or the facilities to test for iodine and other things. Scientists also sometimes come to such an impasse.

We now have two choices:

Choice #1.

When scientists cannot do tests themselves, they sometimes seek the help of other scientists who can provide information to them. Can we find out from the "literature" if some other scientists besides ourselves have tested sea water and table-salt water? We could try the encyclopedia, or books about oceanography in the library. (The reference table below is for the teacher's use only.)

After consulting the "literature," the students may be able to write in their reports that such and such an author reports additional elements in sea water which could not be tested for in the classroom.

Choice #2.

What do scientists do when they lack the technology and even the references to get a job done? For example, what did scientists say about the surface of the moon before they had the ability to go there? What do scientists say about UFO's and the Loch Ness monster? In such cases, scientists do the best they can with what evidence they have, pending the day that they can learn more.

The same applies to us. We can be true scientists by stating, "As far as our testing ability permits, our experiment shows that table-salt water is . . ." Then we must keep an open mind to some day finding out more about it, perhaps even finding out that our first conclusion is in error.

7. Report the final conclusion in the notebook.

Besides the knowledge gained about sea water, perhaps the most important lesson the students can learn from this problem is that science is a testing of ideas, not necessarily a finding of answers, and that tentative answers are subject to revision upon the unfolding of new evidence.

Teacher Background Information.

The following information is excerpted chiefly from a paperback by Warren E. Yasso, 1965, OCEANOGRAPHY, Holt, Rinehart, and Winston, Inc., New York.

The salts in sea water are combinations of many elements, the chief salt being sodium chloride which is ordinary table salt. The total salts in sea water, on the average, amount to 35 grams per 1000 grams of sea water. By contrast, average drinking water also contains numerous trace salts to a level of about 0.05 parts per 1000.

Of the 35 parts per thousand of salt in sea water, about 33.5 parts are sodium chloride or ordinary table salt. The remaining 1.5 parts per 1000 include many elements, among them uranium, copper, aluminum, manganese, silver, gold, and many others.

Iodine in trace amounts (0.0035 parts per million or 0.0000035 parts per 1000) in sea water is more concentrated in certain sea weed and sponges.

The warning in brine shrimp egg hatching to avoid use of iodized salt is a matter of concentration. Iodine, like very many other elements and compounds, can be harmful at some concentrations and either a beneficial drug or even a food at other concentrations. For example, total lack of iodine in human beings produces goiter.

TABLE 7. THE 10 MOST COMMON ELEMENTS WHICH MAKE UP THE SALTS IN SEA WATER

Element	Parts per Thousand
Chlorine (Cl)	18.98
Sodium (Na)	10.56
Magnesium (Mg)	1.27
Sulphur (S)	0.88
Calcium (Ca)	0.40
Potassium (K)	0.38
Bromine (Br)	0.065
Carbon (C)	0.028
Strontium (Sr)	0.013
Boron (B)	0.005

14. BEYOND REEF AND SHORE: THE DEEP OCEAN

Introduction.

As the title of this book implies, it contains investigations which center on shorelines and waters not exceeding wading depth. Shoreline topics alone are ample to keep students (and many scientists) well occupied for years.

Beyond the shoreline and the reef lies a tremendous ocean of gigantic proportions and teeming life which cannot be ignored in the education of children simply because it cannot be reached. If elementary children cannot take a field trip to the bottom of the sea, the bottom of the sea must come into their classroom.

These ocean activities are designed to increase the students' awareness of:

the variety of ocean life,

different animals which live at different levels in the ocean,

some of the physical factors which form the environment and have and effect on ocean animals and on man,

adaptation of animals to the environments in which they live.

Materials Needed For Investigation of the Ocean.

In this study of the ocean, books, pictures, films, and slides must take the place of living animals. Nevertheless the investigations can be as truly activity-oriented as experiments involving live animals in tide pools and classroom tanks.

There is no one recommended reference for investigating ocean life. The class needs to work with as many books, pictures, slides, and artifacts as possible. The greater the selection, the more resources the children can use.

Most children have a wealth of materials at home which they may or may not know they have. Many parents have purchased "nature" books and sets of encyclopedias which include volumes on the ocean and sea life. National Geographics are helpful and are frequently found in homes as well as in libraries. Many popular books have been published about the ocean and ocean life for Hawaii and similar areas, most of them with breathtaking photographs of ocean animals. If every child brings in a book or two from home or the library, the classroom will soon have an excellent reference library to be shared by all the children during this ocean study. Be sure the child's

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*This section on the ocean was developed, classroom tested, and initially written by Dorothy Buddemeier.

name and phone number is written in every book brought from home. For shared library books, put the child's name in the card pocket.

Look also into possibilities for borrowing or renting audio visual materials. Films can be rented or borrowed from the DOE, public library, University of Hawaii, and others. Films, filmstrips and slides can be rented from commercial and service companies. Tourist brochures are usually free. This Nature Study Project is currently preparing a master set of slides for REEF AND SHORE teachers to borrow or copy.

In addition to pictures, printed references, and films, most of the activities in this section require:

-Paper of many colors, sizes, and textures for sculpting animals
-A long roll of butcher paper or the equivalent
-Coloring media such as poster paints, water color, crayons, pastels, or whatever is customarily in use in the given school or grade level
-Glue, scissors, tape
-A reel of fine monofilament nylon fishline for hanging "fish" from ceiling, walls, and in boxes
-Cardboard containers of various sizes as indicated in the specific activities

Scope of the Activities.

No one teacher or class will either want, or be able, to do all the activities described here. Some are overlapping in content to give a variety of approaches to the same topic from which a teacher may choose the most desirable. An activity suggested here may trigger either teacher or students to a further idea which can domino to further and further activities. This is the excitement of being creative.

Some topics are more appealing to the young, others to older students. Again the teacher must decide which topics to initiate, based on the students' interest and ability levels. The echo sounding activities involving mathematics and graphing are definitely for more mature elementary classes.

For each problem or activity presented for student consideration, a few paragraphs of background information are given for the teacher. The background is helpful in guiding the first stages of the activity. Books and references which the students bring in will soon exceed in breadth and depth the notes given here. By that time the students will be on their way and no longer be so dependent on special guidance from the teacher's store of knowledge. They can begin to report to the teacher and their classmates the additional information they have discovered.

DOWN ON THE BOTTOM

Eventually the students will be put to work examining all three "layers" of ocean. Students seem to find it most exciting to begin with the most exotic layer: the benthos.

The word benthos has two usages. Benthos refers to the bottom of the ocean as a place, wheteher that bottom is the bottom of a tide pool, a continental shelf, or the bottom of the deep abyss. Secondly, benthos may refer to an animal or plant which lives on the bottom.

Benthic animals include all the bottom-living tide pool animals studied in previous topics plus all those which live on the deep ocean floor. Some benthos are swimmers or walkers such as brittle stars and clams, and can move around in search of food. Others, like coral and oysters, are fixed in one place and depend on ocean currents or food drifting down for their survival.

Activity:

Make a mural of a benthos community.

Suggested Procedures.

Ask the students if they think life exists on the ocean bottom. If so, what kind? Explain the term benthos. Ask them how many benthic animals they already know from their work in the tide pools. Get a flow of books and pictures coming into the classroom for further references.

Unroll a long sheet of heavy paper the length of the classroom. Move the desks aside so the students can work on the floor. Benthos live on the ocean floor, so why not create a benthos community on the classroom floor? One end of the paper could accommodate animals living in shallow water, the other end deep ocean animals.

Have the children browse through the many reference books they bring in and share in search of benthos. Quite a bit of incidental learning takes place through such relaxed browsing. List on the board the benthos they select to put into their mural. Each child may choose to make one, two, or even three benthos. Aim for variety rather than too much duplication.

The assignment is:

1. Draw and color your chosen benthos.

2. Learn as much as you can about your animals, the information to be shared later with the class.

3. Arrange your animals in a benthic community on the mural, placing those next to one another which relate in some way.

Students should have a picture of their benthos in front of them as they work in order to make the most accurate drawing possible. It is best to draw in pencil first, then fill in with crayons, pens, or paint. Think BIG, and look for DETAILS! Consider how each animal's shape, color, or size helps him to survive. What does he eat? What eats him?

Remind the students that there is a difference between an artistic production and a scientific drawing although either one does not exclude the other. A scientist pays close attention to detail and accuracy.

Not all the children may be able to work on the big paper at the same time. Those wishing to work at their desks may draw benthos on paper the color of the animals chosen or on white paper and color it appropriately. Fill in as much detail as possible before cutting out and pasting it on the main mural.

Some animals such as sea urchins are very difficult to cut out and need to be drawn directly on the large paper.

As each benthos is added, identify it by writing its name, whether common, scientific, or Hawaiian, or all three, near the plant or animal.

Children tend to draw their benthos on the "bottom" edge of the paper because benthos are bottom dwellers. To gain perspective, have the students stand on chairs and look straight down to the floor. They see a whole "area" of floor as the bottom.

Fill in the spaces between the benthos to look like an ocean floor. Glue on or draw paper rocks, sand, limu, etc., perhaps adding arrows to indicate relationships. Possible questions to raise during the finishing stages of the mural:

-How is each benthos designed to protect itself?

-How does the animal's shape, color, outer layer, special devices, such as suction cup feet, aid in the animal's survival?

-What do they eat?

-How do they eat?

-What happens to an overpopulation of one kind of benthos?

-What happens to an underpopulation?

-If the ocean environment changes suddenly, which benthos do you think would have the greatest chance of surviving? Why?

The completed mural may be hung on the wall or in the hallway for all to admire and learn from.

THE SWIMMERS

Nekton are animals that swim freely in ocean water. Nekton are found at all depths of the ocean: surface, middle, and deep down. Nekton are all sizes and shapes. Nekton are sea mammals, fish, and non-fish. Nekton are the swimmers of the ocean.

This activity is designed to stimulate the student's observational skills by paying close attention to details of shape, size, color, and design. By hanging undersea animals from the ceiling, the light fixtures (if permitted), and walls, the children can get the feeling of living in the sea.

Activity:

Let's make our classroom into the ocean!

Suggested Procedures.

Working singly or in small groups the children can look through reference books until they find a nekton they would like to make. Have a sign-up sheet to avoid an overpopulation of sharks! Students may wish to work together to produce a school of fish.

Students can begin work by drawing an outline of their nekton as large as feasible on a sheet of paper. Be sure each student has a reference book in front of him as he works to obtain as much accuracy as possible.

Clip a sheet of paper behind the drawing so that when the outline of the animal is cut out, two identical shapes are obtained. The features can then be filled in and colored on both papers to form right and left sides of the animal. Encourage students to include all details. Ask: If this is a fish, where are the fins located? The gills? Did you remember to draw the scales? What special details does your animal have that makes it different from the others?

Staple the two sides of the fish together in several places around the margin. The animal can then be stuffed with crumpled paper and the last opening stapled shut.

Be sure to put the name of the animal on both sides so that others will be able to identify it, too. It would also be nice to include the name of the "scientist" who drew the fish.

Run twine, or nylon monofilament (nearly invisible) through two places in the top of the animal and hang it from the ceiling or along the walls.

Hang the animals according to the depth of their natural habitat in the ocean. The children may wish to hang schools of the same fish together. Invite the neighbors to come and have the "ocean" explained to them in "scientific" terms by the students.

Teacher Background Information for the Next Several Topics.

We can think of the ocean as divided roughly, and unevenly, into three horizontal layers.

The upper layer, called the photic layer, reaches to a depth of about 600 feet. The upper layer:

- -is penetrated by sunlight of decreasing intensity with increasing depth;
- -has generally warmer temperatures because of sunlight penetration, although temperatures in the upper layer are greatly variable. (Surface waters at the poles may be below freezing while those in the tropics may be 70°F or warmer.);
- -has plant life because of the presence of sunlight;
- -has abundant animal life because of the abundance of plant food;
- -has plankton, which are the "drifters" of the ocean consisting of very small plants and animals which move with the currents;
- -has many and varied currents driven by wind, waves, and other differentials;
- -contains oxygen churned in by the waves.

The middle layer, called the thermocline, is a zone of rapid change. It varies from 1200 to 3000 feet in thickness. The thermocline has:

- -dim twilight ranging into darkness;
- -rapidly decreasing temperatures, from which it gets its name;
- -increasing pressures;
- -few or no currents or churning;
- -no plants;
- -reduced animal life.

Think of the nekton dwelling in the thermocline as living in a well defined zone which has no physical boundaries. It is a water world surrounded by water on the top, bottom, and all sides.

The deep layer, the abyss, is by far the thickest layer, ranging from the thermocline to the bottom, or benthos. The abyssal water has:

- -no light;
- -constant cold;

-great pressures;

-very little movement;

-no plants;

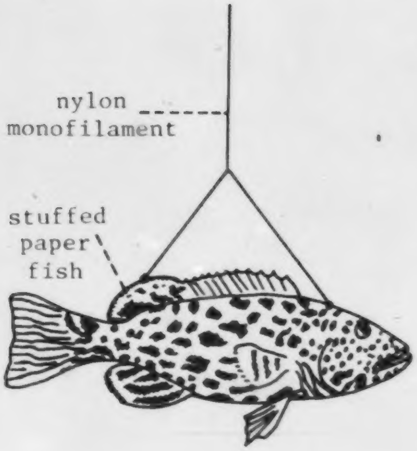
-animals adapted to finding their way around in total darkness and scrounging for food dropped down as detritus or dead bodies from the two upper layers.

Marine life which survives in the bottom layer has had to adapt to great cold, extremely high pressures, and a scarcity of food.

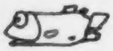
Because of the blackness in which they live, many animals have exceptionally large eyes, or carry their own lights, coming from cells called photophores. The light helps the fish or invertebrate to hunt for food and/or search for mates. Each animal has its own peculiar pattern of lights.

Due to the scarcity of food, most marine life at that depth is small. Every deep-sea animal is either a scavenger or a predator. The scavenger depends on his food floating down from above. Many have huge mouths which are shaped upward to catch anything available. Others have razor-sharp teeth and superlarge jaws which can open to catch prey much larger than themselves.

Students seem to take special delight in studying these "monsters of the deep". Their strange shapes and glowing bodies are fun for the children to recreate.



LAYERS OF OCEAN

Layer	Light	Temperature	Depth	Pressure	Plants	Animals
Upper Layer Photic Zone (shallow surface layer) 	Sunlight Dim	Changeable and Variable from below freezing at Poles to 70°F+ in tropics	Surface about 600 ft	15 lbs/sq in 200 lbs/sq in	Sea Weed and Phytoplankton	Zooplankton and many Nekton
Middle Layer Thermocline (Thin middle layer) 	very dim	50°F to 40°F	2000 to 3000 ft or about ½ mile	1000 lbs or ½ ton/sq in	none	some nekton
Deep Layer Abyss (thick lower layer)	Dark to Black	40°F and Colder	1 mile 2 miles 3 miles 4 miles 5 miles 6 miles 7 miles +	1 ton/sq in 2 tons/sq in 3 tons/sq in 4 tons/sq in 5 tons/sq in 6 tons/sq in 7 tons/sq in +	none	some small nekton
Bottom Benthos 						occasional benthos

AN OCEAN MOVIE

This activity, like the ones preceding and following, is intended to give the children a feel for the major layers of the ocean and for the life they contain.

Activity:

Pretend we are in a submarine with a porthole for viewing life in the ocean. We are on a voyage to the bottom of the sea. Make a movie of the animal life as it swims by or as we pass it on our way down to the bottom.

Suggested Procedures.

Obtain a roll of adding machine paper several inches wide to serve as the "film", or work with a roll of butcher paper stretched the length of the room.

Have the children make up a title for the film and put it at the top. Depths of the ocean need to be indicated on the paper at successive points.

Different groups of children can work on different sections. The film can be made in different portions and then "edited" into a complete movie. Each frame of the movie can be made by drawing directly onto the paper or by making animals on colored paper and then pasting them on at appropriate places.

One group of students might research the depths to which light reaches in the ocean and color the background film accordingly: very pale blue at the beginning of the movie to indicate sunlit waters and deeper blues down to black in the depths.

Some students may work on putting in captions or markers at appropriate levels to indicate temperatures, pressures, and other changes on the way down. Be sure to label all animal life for easy identification.

Students who are working on animal life can include fish, mammals, jellyfish, squid, plankton, schools of fish, eels, prawns, deep sea cucumber, sharks. . .everthing! Also perhaps one animal eating another for survival. The children may wish to include or dramatize the importance of food (both plant and animal) sifting down from the top layers and finally reaching the black depths below. Many deep sea animals have luminescent light organs which "glow" in the blackness. The students could use aluminum foil or special glow-type paper on their animals to create a luminescent effect.

Students may wish to narrate their film on a tape recorder and show their movie to other classes.

SHOE BOX STILL-LIFE DRAMAS

Composing 3-D scenes in shoe boxes fascinated children a generation ago. Creating shoe box still-life dramas viewed through a "pin hole" or "peep hole" have not lost their charm and challenge for modern youngsters.

The purpose here, as usual, is to get the students to delve into a careful study of the ocean and its contents.

Activity:

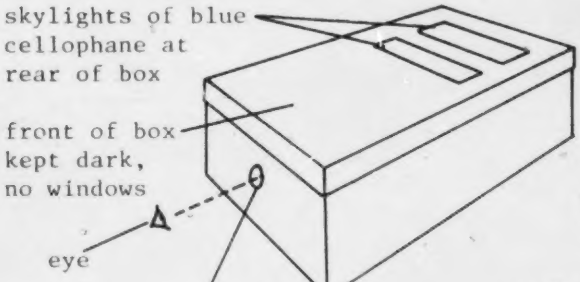
Make shoe box still-life dramas, each for a different layer or different situation in the ocean.

Suggested Procedures.

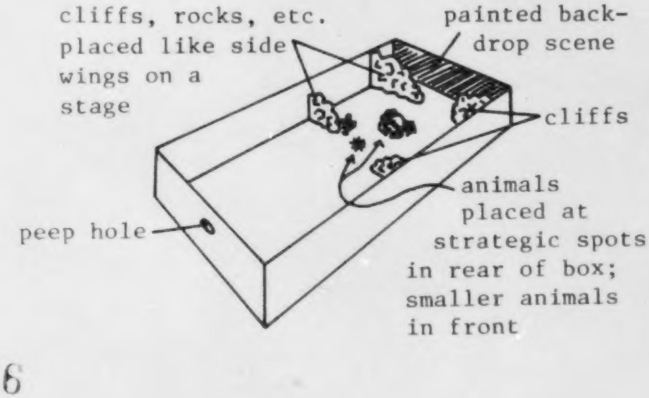
The students may wish to work in groups, two or three on each shoe box. Neighboring groups may work on shoe boxes depicting neighboring scenes. Have the students thoroughly research what will go into their box so that sizes within any one box will be in proportion, and placement of the figures will reflect actual relationships in the sea.

For the assistance of teachers whose youth does not reach back to the days of shoe box still-lifes, a shoe box show in 3-D is made as follows.

VIEW WITH COVER ON


skylights of blue cellophane at rear of box
front of box kept dark, no windows
eye
peep hole

TOP VIEW LOOKING DOWN INTO BOX WITH COVER REMOVED


cliffs, rocks, etc. placed like side wings on a stage
painted back-drop scene
cliffs
animals placed at strategic spots in rear of box; smaller animals in front
peep hole

It takes clever manipulating, a sense of proportion and placement, and hours of absorbing labor to get the animals and rocks into the show so that each one is seen in a pleasing 3-D arrangement replicating real-life relationships.

DEEP OCEAN FIELD TRIPS

During the study of ocean topics may be a good time to schedule a field trip to Sea Life Park. Call ahead for special school tour arrangements and tour guide. Prepare the students for careful observation of the huge reef tank.

The Waikiki Aquarium has display tanks which show fish and other ocean animals not visible to the students during field trips to the beach. See the topic on Waikiki Aquarium at the beginning of this book for arrangements and possibilities.

CARDBOARD REFRIGERATOR BOX

This group project is designed to be used in several ways. Younger children can insert themselves physically into a big box to create an awareness of the deep ocean and its life. For older students the box draws together in one package a study of all three levels of ocean plus bottom topography.

Materials.

- *A very large appliance box such as those used for crating refrigerators or the equivalent.*
- *The usual ocean reference books, paints, paper, glue, as for the other ocean projects*

Activity:

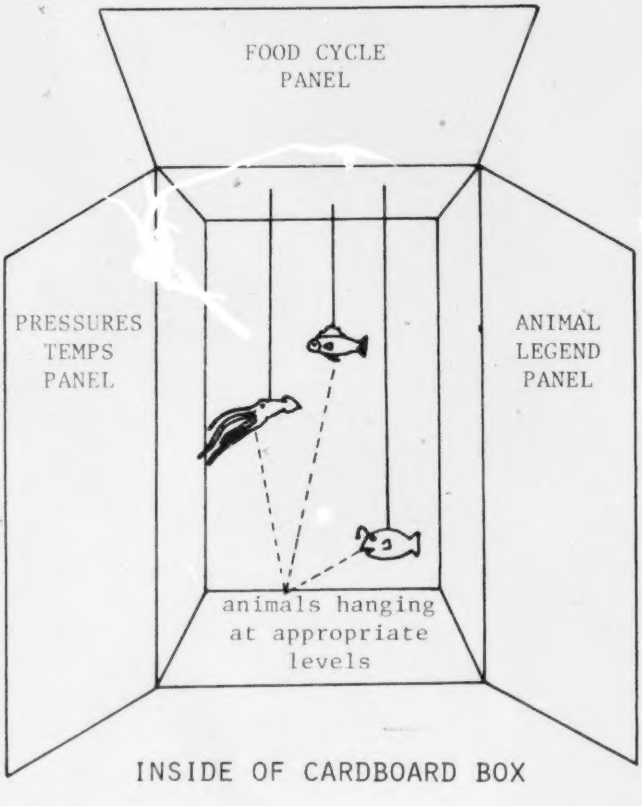
You are a group of famous oceanographers. You have been asked to duplicate a certain area in the Pacific Ocean, recreating all the ocean life found there from the surface to the bottom depths.

Suggested Procedures.

Divide the students into working groups: ocean technicians, physical oceanographers, and marine biologists.

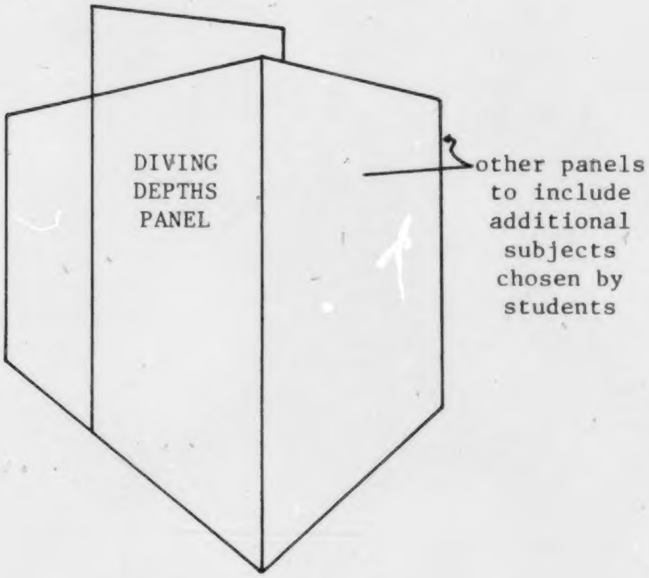
The ocean technicians prepare the box, setting it up sturdily, and painting it inside and out. The upper portion of the inside can be made very pale blue to represent sunlit waters, with graduating shades down to black at the bottom. They might use crumpled paper, tape, or papier mache to create an ocean bottom with ridges, basins, trenches, and seamounts, each marked and identified.

The job of the physical oceanographers is to research the way the box can be divided into three layers. Mark the approximate depths either inside or on the outside of the box. It may be a good idea to exaggerate the width of the upper layer to accommodate the abundant animal life to be placed in it, while telescoping the bottom layer into a section much narrower than in the actual ocean. On the other hand, it is of instructional value to keep the layers in scale to their actual depths to give a visualization of the proportional sizes of layers in the real ocean. Perhaps two boxes are needed! One done in scale and the other showing an exaggerated top layer of ocean.



INSIDE OF CARDBOARD BOX

The side flaps and the outsides of the box can be used to add information on the physical characteristics of the ocean. For example, one flap of the box could display a chart showing temperature and pressure changes at descending depths. Another flap or side might show the various depths which have been explored by man in diving suit, diving bell, submarine, the Trieste, and other methods.


DIVING DEPTHS PANEL
other panels to include additional subjects chosen by students

OUTSIDE OF CARDBOARD BOX

While the technicians are preparing the box, the marine biologists can look through ocean reference books for animals they will choose to make. Relative sizes of the animals should be considered and agreed upon. Encourage as much diversity as possible. Remember to include not only fish but ocean mammals and invertebrates. A moratorium may have to be called on the number of sharks to be displayed to prevent the whole ocean from becoming a shark haven!

Reproduce the animals by stuffing crumpled paper between two matching sides as described in the activity for "The Swimmers". Keep attention of the students focused on scientific detail with comments such as the following:

-Notice the shape of the animal. Reproduce the fins carefully. Scales? Special Color?

-Does the fish have a lateral line?

-Where are the eyes positioned?

-Take careful note of the shape of the mouth. How is this important to the survival of the animal?

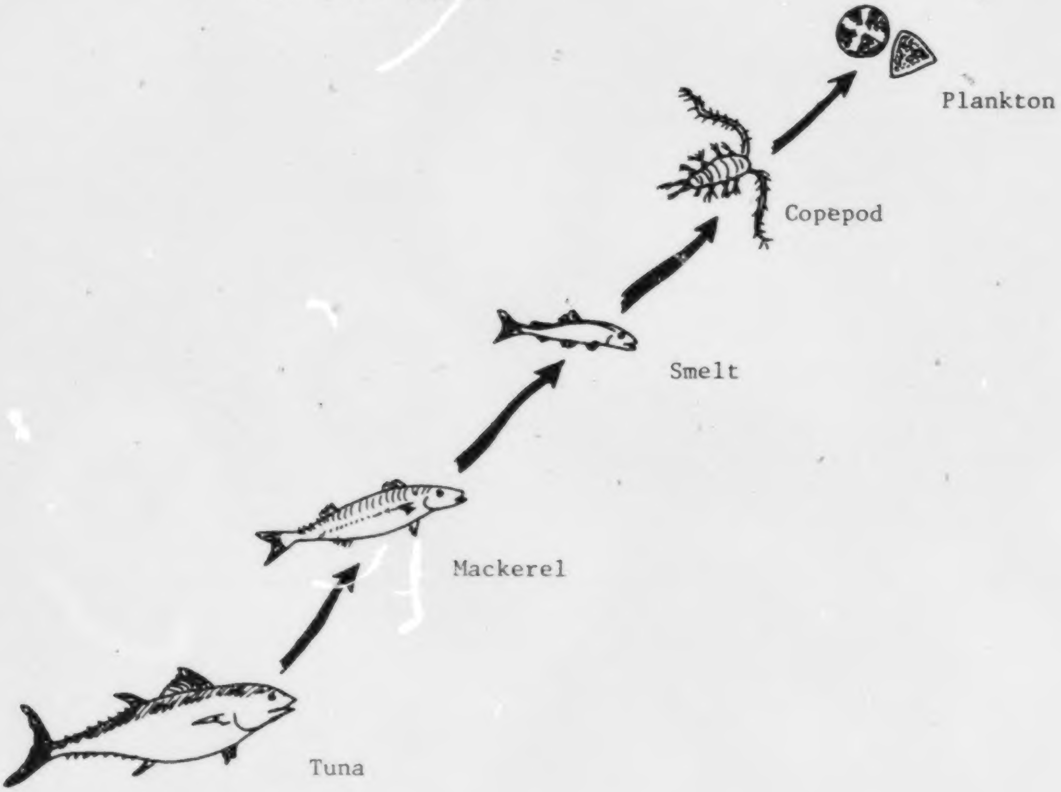
-What other features does the animal have for survival in the depth at which it is living?

Hang each swimming animal at its appropriate depth by nylon lines hung from the ceiling of the box. Thread the line on a needle and poke the needle up through the top of the box, then down again in another spot, tying it securely.

Besides writing the name of the animal on both sides of it, a legend could be developed on one outside part of the box telling some special feature about each animal, as well as its research artist's name. The biologists might use a portion of the outside of the box to portray a food web, indicating who eats whom among the animals "swimming" inside the box.

THE FOOD CHAIN . . .

WHO EATS WHOM?

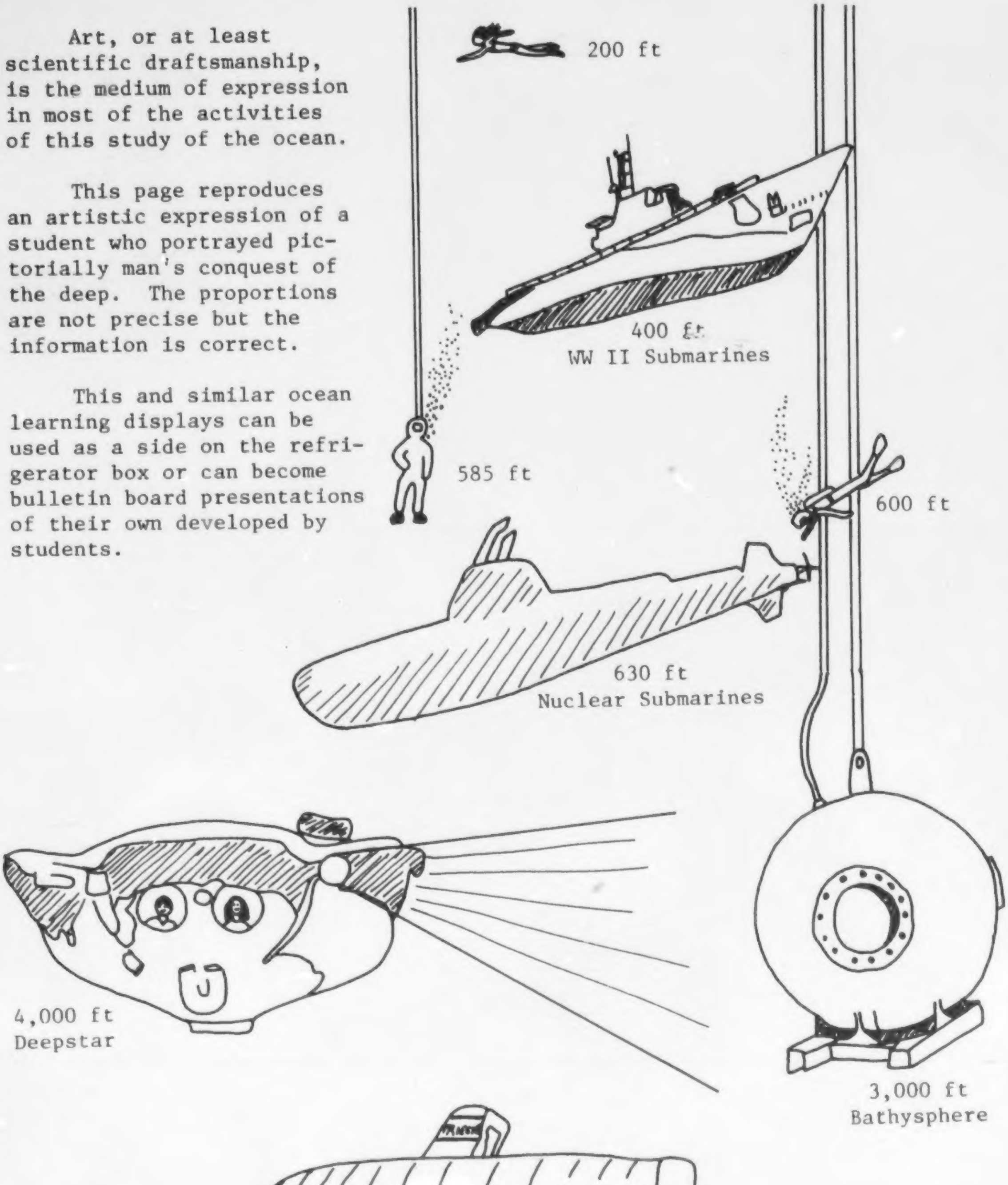


OCEAN ART

Art, or at least scientific draftsmanship, is the medium of expression in most of the activities of this study of the ocean.

This page reproduces an artistic expression of a student who portrayed pictorially man's conquest of the deep. The proportions are not precise but the information is correct.

This and similar ocean learning displays can be used as a side on the refrigerator box or can become bulletin board presentations of their own developed by students.


200 ft
400 ft
WW II Submarines
585 ft
600 ft
630 ft
Nuclear Submarines
4,000 ft
Deepstar
3,000 ft
Bathysphere
35,000 ft
Trieste

SOUNDING BY STRINGS

In the days before echo sounding, sailors relied on a long rope with a weight on the end to measure the depth of water. The rope had knots tied at regular intervals, which were about the length of a sailor's outstretched arms . . . six feet. This six-foot length was called a fathom. The rope was thrown overboard and the number of knots counted indicated the depth of the water. Many navigational charts are still marked in fathoms although today the fathom has been largely replaced by metric measurement.

Maps of land areas are called maps. Maps of ocean areas are called charts. Finding the depth of the ocean by strings or by echoes or by any other method is called sounding.

Materials.

-String marked at one-inch intervals with a weight at its lower end
-Grid paper
-Long stick with marks at every four inches

Activity:

Chart the bottom of an "ocean floor" using the old-fashioned method of sounding with a knotted twine.

Suggested Procedures.

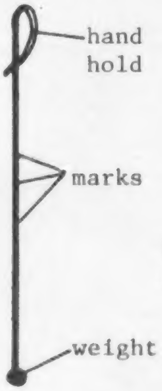
Create a rugged "ocean bottom" from books, boxes, buckets, etc. with an "ocean" above it delineated by desks and tables as shown in the diagram below. The shorelines on both sides of the ocean are the two facing edges of the desks.

Place two strips of masking tape along both shorelines, i.e. the edges of the desks, and mark them at two-inch intervals (or longer intervals if you choose). These points serve as "ports of arrival and departure" for the ship which will sail across the ocean.

Prepare the marking string as follows. Use a length of cord or twine about six inches longer than the distance from the top of the desks to the floor. (This is the depth of the ocean.)

Tie a fishing weight or rock to the bottom end of the string.

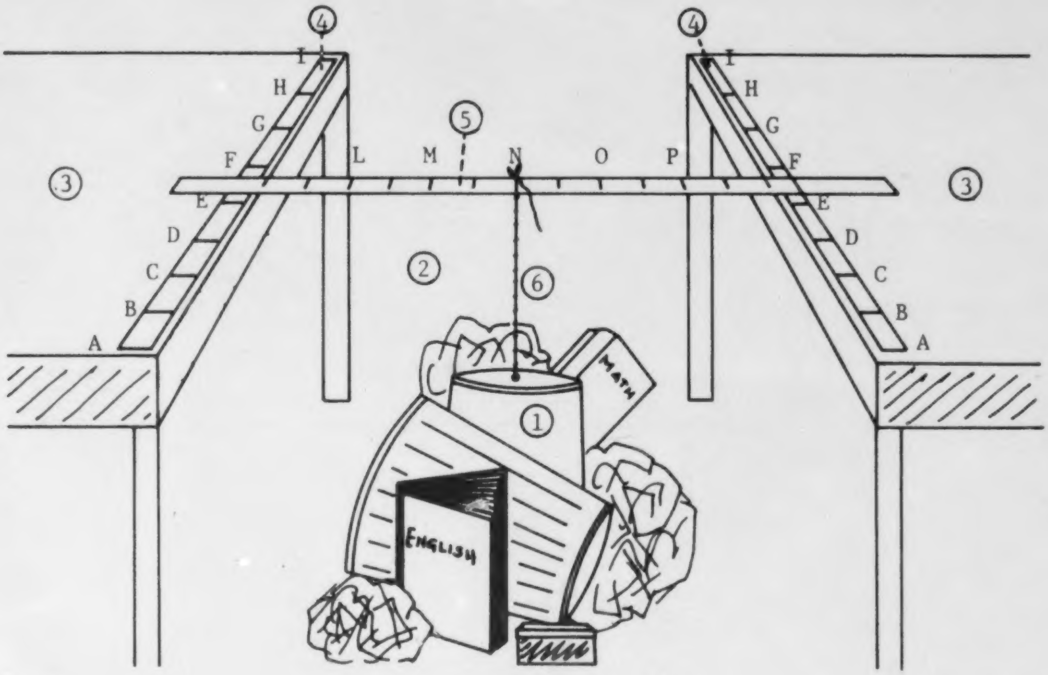
With a marking pen, mark the string at one-inch intervals along its entire



MARKED STRING

length. Each mark on the string can represent a certain number of fathoms or feet or meters as the class decides. (1 fathom = 6 feet or 1.83 meters)

Prepare a yardstick, or other long stick marked at four-inch intervals to reach across the "ocean" between the desks.



① Rugged ocean bottom created by a jumble of large items.

② Ocean.

③ Students desks or tables serving as shorelines of the ocean.

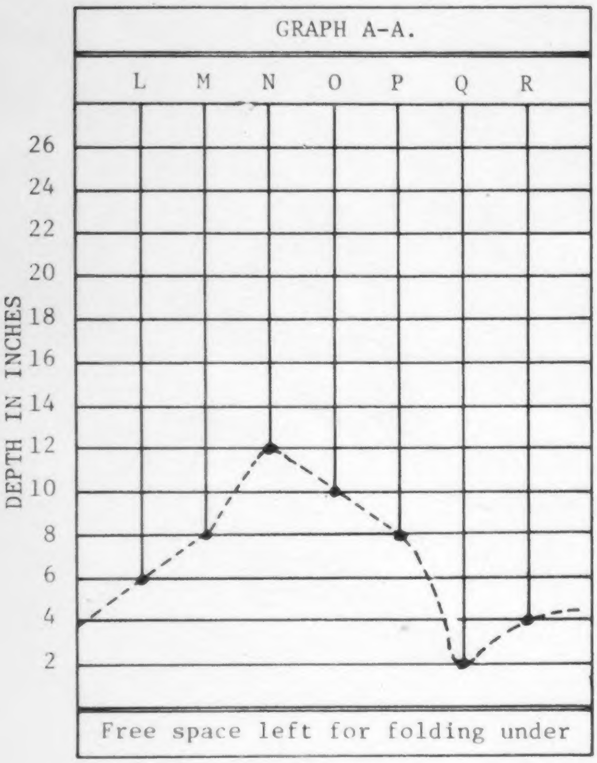
④ Masking tape marked at two-inch intervals and labeled Points A, B, C, etc. to indicate points of arrival and departure of the ship.

⑤ Stick laid across the surface of the ocean to guide the passage across the water. Points L, M, N, O, etc. are four inches apart and from each of these points a depth sounding is taken.

⑥ String marked at one-inch intervals and weighted at the end, used to measure the distance from the ship at the surface of the ocean down to the irregular ocean floor.

Begin work by laying the stick between the two desks from A to A. The stick represents the ship's course across the ocean. Drop the string from point L and count how many inches or marks it goes down until it touches the first obstacle on the bottom. Record this distance on graph A-A. See diagram below.

Move the string to point M and again count how many notches it goes down to the bottom. Mark this on the graph and so on across the entire "ocean" until the other "shore" is reached.



Make one graph for each passage across the ocean. This sample graph shows soundings made when the stick was laid between ports A-A. As the string was dropped from points L, M, N, O, etc., the distance to the bottom is marked at the corresponding place on the graph.

This completes Graph A-A.

Now begin another graph paper to record soundings taken as the ship moves from ports B to B. Move the yardstick to span the distance between points B and B. Drop the string in turn from points L, M, N, etc., measuring how many inches to the bottom from each point. Mark Graph B-B for each sounding.

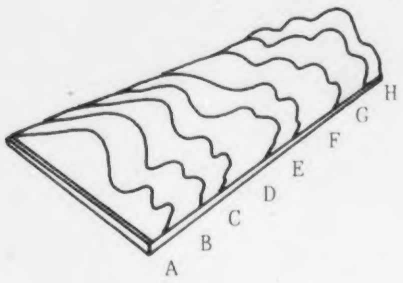
(NOTE: This method of sounding depths presents an opportunity to discuss Samuel Clemen's pen name, Mark Twain. What might the command "mark twain" mean to a sailor on board a depth sounding ship?)

Send the ship across the ocean from ports C to C, D to D, etc., drawing graphs C-C, D-D, etc. for each passage.

Connect the sounding depths on each graph to give a "silhouette" of the shape of the ocean bottom for each set of markings.

Next, cut each graph with a scissors along the silhouette or contour line. Save the bottom part of the graph.

Glue the bottom of Graph A-A to a piece of cardboard so that it stands up. Two inches behind it, glue the bottom contour of Graph B-B so that it stands up, and so on. The bottom of the ocean is reproduced by the series of standing graphs.



Graph A-A is cut out along the contour line and glued so that it stands upright. Graph B-B is cut out and pasted to stand up behind it, and so on. The result shows the contour of the ocean bottom.

SPECIAL CHALLENGE. Have one team set up an ocean bottom and put a dark cloth all around it so the shape of the bottom cannot be seen. Another team comes to sound the depths, taking measurements by "feel" of when the weighted string strikes bottom. After they have completed all of their soundings and made their paper replica of the bottom, take the cloth away and see how well their replica depicts the "real" bottom.

From this activity the students might move on to a study of the topography of the ocean bottom and learn about see mounts, oceanic mountain ranges, and other features. They might also go on to learn about more modern methods of sounding ocean depths.

SONIC WAVE DEPTH RECORDING

In the previous problem, the students "sounded" the ocean bottom by dropping a marked cord, as was done in days of yore. Modern technology "sounds" by timing how long it takes an electronic beep to reach the ocean floor and be reflected back. The following problem develops the basic idea that travel to and from a destination can be used as a measure of distance. The "traveler", in this case, is not a sound wave but a team of students jogging to and from a given point.

At the end of this activity, students will not be qualified as crew members aboard an oceanographic vessel, but they may have a general idea of the basic principle involved in sonic depth recording.

Problem 1. TIME AS A MEASURE OF DISTANCE BANDS 2, 3

Materials.

-Stop watch or watch with sweep second hand
-Meter or yard stick to lay base line

Problem:

How can time be used as a measure of distance?

Can distance to the ocean floor be measured by this method?

Suggested Procedure.

This activity can be done by teams of students working separately. It can also be done by the class as a whole with a few members serving as the joggers while others time the action and do the calculations.

1. Measure off a distance in the school yard to serve as a base line, e.g. 20 or 30 meters.

2. Have several children, the "echo sounders", link arms and job back and forth over the base line several times at an even pace. A team with linked arms tends to keep a steadier pace than a lone runner.

3. Calculate the average time it takes the joggers to cover the known distance. This is their rate of speed, e.g. 30 meters in 10 seconds calculates out to be three meters per second.

4. Select an object of unknown distance, e.g. a tree on the far side of the campus but within visual distance of the group. In this case the tree represents the ocean bottom.

5. Have the "echo sounders" jog to the selected object and back once, while the others time their performance.

6. Divide the time by two. Discuss with the students why the time is halved. (The joggers cover the distance twice, just as a sound wave from a ship goes to the bottom and then returns, covering the distance twice.)

7. Calculate the distance by multiplying the rate of speed by the time it took to cover the distance one way, e.g. if the joggers took 30 seconds to make the round trip to the tree, then 30 ÷ 2 = 15 seconds to go one way. 15 seconds x 3 meters per second = 45 meters, the distance to the tree.

8. Discuss with the students how a sound wave sent from a ship to the bottom of the ocean and back is like a jogger going to the tree and back. If we know the speed of sound in water, we can calculate the distance to the ocean bottom by multiplying time of the sound wave to cover the distance times the speed of sound in water.

   Student work in encyclopedias and other references can bring forth information on the speed of sound in water, and its variation in speed with different temperatures, densities, etc. (This is represented in our model by slight changes in the joggers' speed.); what SONAR means (Sound Navigation Ranging); what kind of sound wave is sent out; the kinds of ships which do sonic depth recording; what would happen if the wave bounced off a whale or a submarine; etc., etc.

OCEAN TOPOGRAPHY

Topography means the mapping or charting in detail of the physical features of a region in a way which shows relative positions and elevations. The thrust of this investigation is not to memorize lists of new words and their definitions but to experience or re-create the topography of the sea floor through games and activities.

Choose only one or two suitable activities from among the following problems and games. An abbreviated set of vocabulary words and background information is given at the end of the topic as an initial aid to the teacher in getting started. Books and references brought in by the students for the project can augment this beginning information.

Problem 2. OCEANIC MOUNTAIN RANGES BANDS 2, 3

The longest mountain range in the world lies under the ocean.

Materials.

- *Relief or contour maps of the ocean floor (National Geographic or others)*
- *Slides or overhead transparencies if available*

Activity:

Find an underwater mountain range that touches every ocean. What different names can you find for it as it travels from ocean to ocean?

How does the range vary in height and size?

Suggested Procedures.

Settle the students in groups around world maps of the ocean floor.

An appropriate place to have the students begin to trace the oceanic mountain ranges is the northern portion of the Mid-Atlantic ridge where it breaks the surface of the water forming the Icelandic Islands.

Note the continuation of the mountain range down the North and South Atlantic, past the Cape of Good Hope, into the Indian Ocean, on toward New Zealand, then east to Cape Horn, and finally upward in the eastern Pacific where it trends landward into the Gulf of California.

The students might consider not only variations in the actual height of the ridge measuring from the ocean floor, but also its varying depths below the surface. Consider also the secondary ridges spreading out from both sides of the center "crack".

Older students may find references in the newer encyclopedias and in other references to plate tectonics, the "splitting" of the ocean floor, plate movements, magnetic reversals, and other related ocean floor topographical findings on which they can report.

Problem 3. PHYSICAL FEATURES OF THE OCEAN FLOOR BANDS 2, 3

Materials.

-*Topographic maps of the ocean floor, one set per each group of students*
-*Additional pictures as available*
-*Paper and pencils*

Activity:

Identify the prominent topographical features of the ocean floor.

Learn their names and whatever else you can about them.

Suggested Procedures.

This factual learning activity might be pursued as a game. Here are two gaming ideas which might be useful.

Game 1. Rival Explorer Groups: Let each group of students be a group of explorers from rival countries or rival companies. The group with the best knowledge of the sea floor is in the best position to further its national or business cause. See which team can achieve best acquaintance with the names, locations, and types of oceanic trenches, ridges, abyssal plains, canyons, etc. You might limit the game by selecting only certain features to be identified, or certain areas of ocean to be explored. Invent a prize or award or advantage for the winning country or business.

Game 2. Oceanic Bingo: An unmarked chart of the ocean bottom is spread before each team. Each team is supplied with small cards. On each card is written the name of an ocean bottom feature. As the teacher, or leader, calls out "guyot", or "trench", etc., the players place a name on the chart in the appropriate spot. The winning team is the one with the most features correctly covered.

Make up rules, add and subtract game features which make the game suitable to the class which is playing.

Problem 4. REPRODUCING THE OCEAN FLOOR BANDS 2, 3

Materials.

-Medium for molding (clay, papier mache, or other)
-Chart of the ocean floor from which to copy
-Paint

Activity:

Mold an ocean floor from clay or papier mache.

Include as many features as possible.

When dry, paint and label the chart.

Suggested Procedures.

Molding a three dimensional relief may from a chart printed in two dimensions can tax the ability of the students in reading and understanding charts and interpreting markings indicating depths and elevations.

This may be a task for a few students to pursue as a project as they have time. It may be a task for the entire class, each group in the class working on a different portion of the ocean floor.

The dried relief map can be painted in appropriate colors, such as light blue on higher elevations, black in deep canyons, red where volcanism is active, etc. A legend can explain each color.

Teacher Background Information.

The ocean floor can be divided into three parts: the continental shelf, the continental slope, and the deep ocean basin. The basin alone comprises

5/7ths of the total sea area or one half of the earth's surface.

The continental shelves border most of the earth's continents. They average 75 kilometers (46 miles) wide and are the shallowest part of the ocean, sloping gently away from the shore to a depth of about 500 feet. Sunlight penetrates the water and the area is rich in plant and animal life. More fish live here than any other part of the ocean. The ice age, silt and erosion from rivers, and the surf all helped to shape the shelves.

The shelves plunge suddenly into the continental slopes. At the bottom of the slopes oceanographers have found deep gorges and canyons. They were believed to have been cut into the slopes by powerful undersea avalanches called turbidity currents.

The deep ocean floor begins at the foot of the continental slopes. Although some trenches in the floor are more than seven miles (35,000 feet) deep, the average depth is two and a half miles. All peaks, cones, ridges, and cliffs on the ocean's floor have been preserved unchanged, instead of being worn away by the elements, as they would have been on land. Hence underwater mountains have steep sides as well as gentle rises.

Vocabulary.

Deep Sea Trenches are usually shaped in a deep, narrow V. All are near a land mass. Trenches mark the place where a plate of moving ocean floor dips under the edge of a continent. If a trench is near an island chain, the trench is on the ocean side of the islands. The Mariana Trench in the Pacific Ocean is the deepest - about 10,915 meters (35,800 feet).

Fracture Zones are crevasses at right angles to a ridge.

Seamounts also called sea knolls or abyssal hills, are isolated mountains that do not reach the surface of the sea.

Guyot (pronounced ghee-oh) is a flat topped seamount or submarine volcano.

Submarine Canyons are relatively narrow sea valleys with high, steep, and rocky wall.

Deep Sea Fans are underwater equivalents to deltas on land.

Abyssal Plains are deep, flat areas of ocean bottom covered with ooze. Ooze is a combination of the remains of dead plants and animals which have died in the water and settled to the bottom plus volcanic dust, ash, silt, and sand.

A LOOK TO THE FUTURE

This Teacher's Guide on REEF AND SHORE is not finished. It has simply come to an end on page 265. On the project director's desk sit many folders labelled by topic. Some contain drafts of problems, activities, and procedures not yet tested for validity; others contain notes on classroom ideas not yet drawn together in publishable format.

The papers include items such as rough write-ups on flatworms, featherworms, plain worms, and other mud dwellers; notes on the Portuguese Man-o-War, jelly fishes, sponges, nudibranches; a set of experiments on tilapia; and an outline on shore birds. A Sheaf of papers contain ideas about the geology of shoreline rocks; a set of activities on sand: how the students can examine it for size, texture, composition, and enjoy making castles with it while checking its cohesion when wet and dry; a study of waves and wave patterns and how they break and bend at the shoreline. Waiting in draft form is a series on fish anatomy and physiology: fish scales, fish senses, swimming dynamics, and behavior; a partially tested and written experiment on biological clocks; a consideration of phyto- and zooplankton. Some initial planning went into the heroic idea of doing an inventory for teachers' reference of potential shoreline study areas and what can be studied at each place. Best (or worst) of all is an entire section on marine ecological studies including food chains, food webs, trophic levels, comouflage, and balance in marine environments.

Some day all these topics can be finished and tested. Meanwhile teachers in the classrooms of Hawaii are creating still further ideas to add to the pile. They will soon find from classroom experience the strengths and weaknesses of topics printed here. In some future Eden when all these items and events conjoin, we shall have Edition Two of REEF AND SHORE. The second edition may be twice as thick as this first one and it may take until the 1980's to get to the printer. Meanwhile we take pleasure in giving the teachers this 1976 version of REEF AND SHORE and beg their continued gracious and generous feedback on this initial effort.